01 SOLID FUELS

Sources, winning, properties

14/00665 A numerical study of stress changes in barrier pillars and a border area in a longwall coal mine

Shabanimashcool, M. and Li, C. C. *International Journal of Coal Geology*, 2013, 106, 39–47.

In longwall mining, stope voids are filled by caved-in rock materials. Cave-in and fracturing of roof strata cause severe disturbance to and stress changes in the host rocks. The study site is the Svea Nord coal mine. Longwall mining method was implemented to extract coal at the study site. It is intended that the coal in the border area on one side of the longwall panels will be mined after completion of the longwall mining. There is a concern about how the longwall mining affects the stress state in the border area and how the stress changes would affect future mining in the border area. Three-dimensional numerical modelling was conducted to consider the above concerns. Two models were constructed in the study. The first one is a local model that includes only two panels to study how the stresses in the barrier pillars are changed during panel mining. The second one is a mine-scale global model that includes all the panels with the aim of studying the disturbance to the border area by the longwall mining. The simulations show that the stresses in the barrier pillars fluctuate up and down during mining because of periodic cave-in events behind the longwall face. A failure zone of about 12 m exists in the wall of the barrier pillar. A large portion of the barrier pillar is still intact and is thus capable of protecting the border area. A disturbed zone of about 20 m is found to have developed in the wall of the main tunnels on the side of the border area after all the longwall panels have been mined out. The stress state in the remaining portion of the border area remains unchanged. Therefore, by considering a pillar with width of 25–35 m into the border area along the access tunnels, it will be possible to mine the rest of the border area with room-and-pillar method in the future.

14/00666 CH_4 and CO_2 sorption isotherms and kinetics for different size fractions of two coals

Han, F. *et al. Fuel*, 2013, 108, 137–142.

The aim of this study is to understand details about the sample size influence on the CH_4 and CO_2 sorption behaviours of coals. Two anthracites (YQ and QS) were selected, ground and sieved. Four size fractions (from powder size −0.354 mm to the lump size 4–10 mm) were tested. The manometric method was used to determine the CH_4 and CO_2 sorption isotherms and kinetics. The unipore diffusion model was selected for sorption kinetic modelling. Although the compositions of the different size fractions generally exhibit slight variations the isotherms with different sample basis (air-dried, ash-free or dry-ash-free) are not apparently different, except for the largest size YQ sample that contains significantly higher amounts of minerals. However, the 'ash correction' or the 'ash-moisture correction' made the sorption isotherm of the largest size YQ sample deviate from the main trend. The predicted effective diffusion coefficients of CH_4 and CO_2 for both coal samples increase, however, unexpectedly with the increase of the sample size. It is probably due to the differences in the mineral contents, the improper estimation of sample size, and the differences in pore structures.

14/00667 Effect of blending ratio on combustion performance in blends of biomass and coals of different ranks

Moon, C. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 232–240.

Combustion measurements were conducted to investigate the combustion characteristics of blends of biomass and coals of different ranks. A laboratory-scale slit burner, which more accurately represents the conditions for a practical flame with a high heating rate and jet velocity, was adopted in the present work based on thermal analytical results. The results of a thermogravimetric analysis revealed that the great amount of volatile matter in the biomass and the rapid emission of this volatile matter under low temperature, which contribute to the accelerated ignition at a lower temperature, increased the particle surface temperature and enhanced the reactivity on the surface of a low-rank coal. The combustion performance of a low-rank coal could be improved with a biomass addition, while the biomass addition had no apparent impact on the combustion performance of a high-rank coal. In addition, combustion characteristics such as the mean flame temperature and reaction region were investigated using a laboratory-scale slit burner. Adding 10% biomass to the blends improved the combustion efficiency of a low-rank coal. In the co-combustion of a low-rank coal and biomass, this 10% biomass addition enhanced the ignition and promoted reactivity in the volatile reaction region through a synergetic effect between the low-rank coal and biomass.

14/00668 Explaining the relationship between common coal analyses and Afghan coal parameters using statistical modeling methods

Chelgani, S. C. and Makaremi, S. *Fuel Processing Technology*, 2013, 110, 79–85.

This study investigates the effects of proximate, ultimate and elemental analysis for Afghan coal samples on Hardgrove grindability index (HGI), gross calorific value (GCV) and ash fusion temperatures (AFTs) by using multivariable regression (MR) and adaptive neuro-fuzzy inference system (ANFIS) to increase information about the properties of the Afghan coal. Statistical modelling (MR and ANFIS) indicated that coal parameters (HGI, GCV, AFTs) can be predicted with high accuracy, where GCV, AFTs, and HGI were estimated by $R^2 = 0.99$, 0.95 and 0.94, respectively. The small difference between the estimated parameters and their actual values shows that these accurate results can be also applied to estimate coal properties in other coal resources of Afghanistan.

14/00669 Extractability of biomarkers from high- and low-vitrinite coals and its effect on the porosity of coal

Furmann, A. *et al. International Journal of Coal Geology*, 2013, 107, 141–151.

The influence of two solvents on the degree of bitumen extractability and the porosity of the extracted coals was investigated using two high-volatile bituminous coals with different petrographic composition. The Springfield Coal (vitrinite-rich) and the Lower Block Coal (vitrinite-poor) from the Illinois Basin were Soxhlet-extracted with methanol (CH_3OH) and dichloromethane (CH_2Cl_2). The abundances of three selected groups of biomarkers extracted from both coals were compared: (1) *n*-alkanes plus pristane and phytane; (2) hopanes; and (3) three- and four-ring aromatic hydrocarbons (phenanthrene, anthracene, fluoranthene and pyrene). Overall, the extracts of the vitrinite-poor Lower Block Coal contained greater amounts of *n*-alkanes and hopanes, whereas aromatic hydrocarbons were extracted in greater quantities from the vitrinite-rich Springfield Coal. Fourier transform infrared spectroscopy and gas chromatography/mass spectrometry confirmed that the average lengths of aliphatic chains were greater in CH_2Cl_2 extracts from both coals. For the Lower Block Coal, the aromaticity of extracted organic matter was greater in the CH_2Cl_2 extract than in the CH_3OH extract. Both coals showed an increase in microporosity (< 2 nm; measured by CO_2 adsorption) after solvent treatments. In addition, the mesopore surface area (2–50 nm, measured by N_2 adsorption) was reduced likely because of a shift in the size distribution of mesopore diameters towards those of macropores (i.e. > 50 nm). The analyses of compound classes present in the extracts and resultant porosity changes in the extracted coals provide useful insights into the structural and molecular differences in two bituminous coals of different maceral compositions.

14/00670 Ignition of co-axial turbulent diffusion oxy-coal jet flames: experiments and simulations collaboration

Pedel, J. *et al. Combustion and Flame*, 2013, 160, (6), 1112–1128.

The primary purpose of the study is to obtain physical insight into the stability of an oxy-coal flame as a function of changing primary gas composition (CO_2 and O_2). Flame stability had been measured elsewhere using the optical measurements of the flame stand-off distance in a 40 kW pilot facility. Large eddy simulations (LESs) of the facility were performed using a multi-scale simulation tool and provide additional insight into the experimentally observed data. The importance of factors such as heterogeneous reactions, radiation or wall temperature can be better understood thanks to simulations. The effects of three parameters on the flame stand-off distance were studied. Simulation predictions were compared to experimental data using the data collaboration method. Overall, this study shows that high-fidelity LES simulations combined with experimental data can yield a deeper understanding of very complex coal flames, indicate where experimental uncertainties lie and be a valuable tool for design, retrofit and scale-up of oxy-coal burners.

14/00671 Influences of chemical structure and physical properties of coal macerals on coal liquefaction by quantum chemistry calculation

Feng, J. *et al. Fuel Processing Technology*, 2013, 109, 19–26.

Significant progress has been made in the simulation of coal liquefaction by the quantum chemistry calculation among similar rank coals. Three Chinese bituminous coals from Lingwu, Shendong and Pingshuo were chosen as samples and evaluated. By means of density gradient centrifugation, six kinds of coal macerals with greater than 95% purity were obtained. Using Materials Studio 4.0 quantum chemistry software the hydro-liquefaction activity differences were analysed by the bond orders of six maceral model structures.

Calculation results were compared with specific surface area and average pore size data from nitrogen physical adsorption. It showed that the specific surface area of macerals had no direct relation with their liquefaction yield, while their average pore size and liquefaction yield were shown to be positively correlated. Also, chemical bond cleavage activity of coal structure units influenced liquefaction yield. Under the solvent cycle condition, the capacity of coal liquefaction is potentially decided by the efficiency of hydrogenation to stabilize the free radicals, and also by coal pore size. The rapid cycle of solvent increases the liquefaction yield due to more additional fresh solvent added. The chemical structure and physical properties of Shendong coal displayed much better liquefaction capability than other coals examined.

14/00672 Kinetic characteristics of pulverized coal combustion in the two-phase flow

Li, Z. *et al. Energy*, 2013, 55, 585–593.

The kinetic characteristics of pulverized coal combustion in the two-phase flow were studied using the micro fluidized bed kinetic analyser (MFBKA) so as to get closer to the actual working condition. On the basis of the performance of CO and CO_2 emissions, the effect of various operating parameters, such as reaction temperature, superficial gas velocity, coal particle size, oxygen concentration and coal properties, on the combustion rate was investigated. The yield ratio of CO to CO_2 remained 1 : 1 until the reaction temperature exceeding 850 °C and then decreased gradually, indicating that the combustion mechanism changed at such temperature. The increase of superficial gas velocity and oxygen concentration and the reduction of coal particle size had positive effects on promoting the combustion process, but their contributions became feeble as the superficial gas velocity and the oxygen concentration were respectively greater than 0.10 m/s and 50 vol.%, and the coal particle size was smaller than 74 μm. The relations of reaction rate constant with various operating parameters were established. The kinetic parameters of pulverized coal combustion determined by MFBKA presented the same changing tendency as the results of thermogravimetric analysis, but the former apparent activation energy is relatively lower because of its optimized kinetic conditions.

14/00673 Paleoenvironmental settings of the Sofia lignite basin: insights from coal petrography and molecular indicators

Stefanova, M. *et al. International Journal of Coal Geology*, 2013, 107, 45–61.

Compositions of Balsha lignite, Sofia coal-bearing basin, Bulgaria and carbonaceous shales are studied by petrological and geochemical proxies. The macropetrographic characteristic of profiles is relatively constant. The lignite is generally composed of dull matrix coal containing significant amounts of xylite fragments. The typical microscopic constituents of the lignite are the ulminite, and less frequently textinite lenses, scattered within attrinitic groundmass. The maceral composition of the organic matter in carbonaceous shales does not differ significantly from that of the lignite samples. Biomarker assemblages of the extractable portions are determined by gas chromatography–mass spectrometry. Additional information for the compositions of residues after extractions is obtained by tetramethylammonium hydroxide (TMAH) thermally assisted hydrolysis/methylation. Petrographic contents, lipid assemblage and TMAH thermally assisted hydrolysis/methylation data imply that the original peat bog is formed in fresh-water forest swamp preferably composed by gymnosperms. Polar diterpenoids argue for *Cupressaceae s.l.*, *Taxodiaceae* as the most probable vegetation. For one of the profiles appreciable angiosperm rich herbaceous-type flora contribution is assumed. Polar oleanane triterepenoids and their aromatized derivatives argue for angiosperm input. The relevance of A-norfriedel-8-en-10-one/friedelin ratio for groundwater level appraisal is discussed. It admits long period of high water level in the paleomire. High content of vanillyl structures and subordinated presence of syringyl units in products of TMAH thermally assisted hydrolysis/methylation are hint for Gymnospermae input in the paleoswamp and Angiospermae contribution to one of the profiles. Cinnamyl phenolic units, indicating non-woody angiosperm vegetation presence, are registered as well. Flavonoids in products are considered as taxonomic markers of *Cupressaceae* plants in the paleoswamp.

14/00674 Petrophysical characterization of Chinese coal cores with heat treatment by nuclear magnetic resonance

Cai, Y. *et al. Fuel*, 2013, 108, 292–302.

For the past decades the nuclear magnetic resonance (NMR) technology has gained acceptance as a petrophysical tool for evaluating reservoir properties. Comprehensive reservoir evaluation requires determination of irreducible fluids, movable fluids and permeability. Although the NMR petrophysical properties of coals have been studied for decades, the impact of heat on these properties (pore size distribution, pore structures, porosity and permeability) has not yet been systematically investigated. However, these are key properties for coalbed methane (CBM) generation and production. Therefore, they may have significant implications for the effects of heat from geothermal dynamics and magma intrusion on CBM concentration and transport in coals with different ranks. Thus, NMR experiments for samples treated at different temperatures (from 25 to 375 °C) were designed to study the variation of petrophysical properties of three Chinese coal cores with different ranks. Results show that NMR transverse relaxation (T_2) distributions of the water saturated cores strongly relate to the coal pore structure and coal rank. Furthermore, based on T_2 cutoff time method, five models for calculating the permeability of coals to water were evaluated. The results show that the Schlumberger–Doll Research model and its improved model provided the best estimation among the five models because these two models are generally able to represent the matrix permeability of the coal, based on the comparison between the results from measured gas permeability and NMR permeability models. Further calculations indicate that the porosity of all three different rank coals have an increasing trend with exposure to temperature, but with different increments for these coals. The low-volatile bituminous coal has the largest increment (9.44%), which is an improvement of more than 200% from its original porosity (4.02%). While the permeability has no similar trend for these three rank coals after heat treatment due to the strong heterogeneity of pore structure in coals. The results may suggest complex microfractures widths change for forming/closing at different heating stages.

14/00675 The Petřkovice Member (Ostrava Formation, Mississippian) of the Upper Silesian Basin (Czech Republic and Poland)

Hýlová, L. *et al. International Journal of Coal Geology*, 2013, 106, 11–24.

The Petřkovice Member (Carboniferous, Mississippian, Early Namurian) is in many ways the most interesting lithostratigraphic unit of the paralic part of the Carboniferous coal-bearing Upper Silesian Basin (described as the Ostrava Formation in the Czech part or as the Paralic Series in the Polish part). Petřkovice Member represents a transition between the non-coal-bearing Carboniferous flysch sedimentation of the Moravian-Silesian Basin and the coal-bearing sedimentation of the Upper Silesian Basin. The paper includes maps of the basic sedimentological parameters of this unit – thickness, sand content and coal-bearing capacity. The thickness of the Petřkovice Member ranges from approximately 50 m in the east of the basin to around 770 m in the west and has a clear polarity in the NNW–SSE direction. Sand content ranges from 23% in the west of the basin to more than 90% in the east. Its polarity is approximately the same as its thickness. The greatest coal-bearing capacity, expressed as total thickness of the coal layers with a thickness greater than 10 cm, is known from the Czech part of the basin, where it exceeds 25 m in places. In the majority of the Polish part of the basin the Petřkovice Member's total coal content is less than 5 m, at times up to 7 m. However, in this part of the basin their level of recognition is very low. On the basis of the above parameters, three assumed zones of differing mobility in the basin's bedrock are defined in the Petřkovice Member's area.

14/00676 The thermal evolution of asphaltene-bound biomarkers from coals of different rank: a potential information resource during coal biodegradation

Muhammad, A. B. and Abbott, G. D. *International Journal of Coal Geology*, 2013, 107, 90–95.

Asphaltenes from coals of different rank were oxidized using ruthenium tetroxide with the aim of investigating the changes in bound biomarker distributions as a function of increasing maturity. There is preliminary evidence for epimerization of bound hopanoid biomarkers from the biological configuration into the more stable geological configuration. The 22R ↔ 22S epimerization in the bound $17\alpha(H),21\beta(H)$ homohopanoids lags behind the corresponding isomerization in the maltenes between mean vitrinite reflectance (R_o) values of *ca.* 0.5–0.7%. In general, the asphaltenes evolve towards a more thermally stable structure with decreasing amounts of aliphatic moieties and increasing amounts of lower molecular weight side chains relative to the higher molecular weight ones. Bound biomarkers in coal asphaltenes could be important sources of information particularly where free hydrocarbon biomarkers have been altered or completely lost to biodegradation which occurs during the generation of microbial gas.

14/00677 Thermal dissolution of Shenfu coal in different solvents

Shui, H. *et al. Fuel*, 2013, 108, 385–390.

The thermal dissolution (TD) behaviours of Shenfu (SF) coal, a kind of Chinese sub-bituminous coal at different temperatures in different solvents were investigated in this study. The results show that almost all of the ash in the raw coal was transferred into the TD residue. The TD soluble yield (TDSY) of SF coal increased with the raising of TD temperatures from 300 to 360 °C for 60 min with 1-methylnaphthalene (1-MN) as solvent, and the highest TDSY of 56% was obtained at

360 °C. Further raising temperature to 380 °C, the TDSY decreased rapidly. The highest TDSY obtained at 360 °C can be attributed to the partial pyrolysis of SF coal. When *N*-methyl-2-pyrrolidinone (NMP) or methanol was added into 1-MN, the TDSY greatly increased. Especially, when 20% NMP was added, the TDSY reached up to 75%. Since NMP is a strongly polar solvent, it can dissociate the strong cross-links in the coal, resulting in the increase of the TDSY. However, when both of NMP and methanol were added into 1-MN, the TDSY dramatically decreased, indicating that there are some interactions between the two solvents. Crude methyl naphthalene oil (CMNO) was a more effective solvent for the TD of SF coal than 1-MN, and its TDSY achieved 66% at 360 °C for 60 min. Addition of various polar solvents into CMNO, the TDSY decreased, especially for the addition of methanol, the TDSY decreased by about 15%. The result indicated that methanol may react with some active fractions in CMNO, resulting in the decrease of the TD effect. When both of NMP and methanol were added into CMNO, the TDSY dramatically decreased due to the interaction between them. The TD soluble fractions (TDSFs) obtained from various solvents were characterized by elemental and FTIR analyses.

Preparation

14/00678 Classification performance evaluation of floatex density separator for coal fines

Kumar, C. R. *et al. Fuel*, 2013, 108, 303–310.

Floatex density separator (FDS) is an advanced hindered settling classifier and autogenous teetered bed separator, which utilize particle settling rates to segregate different particles according to size, shape and density. In coal washery FDS is being employed as pre-concentrator as well as classifier. Though enough literature is reported on FDS for coal cleaning or de-shaling purpose, but there was no appreciable work carried out on the effect of process variables on classification performance while treating coal. Therefore, the present study focuses on effect of different process parameters like teeter water flow rate, set-point, feed rate and pulp density on particle classification while treating fine coal. Statistically designed experiments were carried out and their effects on performance in terms of yield to under flow, cut size (D_{50}) and classification efficiency (E_P) has been evaluated. Different regression equations were developed to describe and predict the performance of floatex density separator.

14/00679 Conversion of large coal particles under O_2/N_2 and O_2/CO_2 atmospheres – experiments and modeling

Guedea, I. *et al. Fuel Processing Technology*, 2013, 112, 118–128.

Conversion under O_2/N_2 and O_2/CO_2 atmospheres of coal particles of sizes typically used in fluidized bed combustion is studied by means of experiments and modelling. Experiments are conducted for six different fuels in a thermo-gravimetric oven, for different gas atmospheres and temperatures, providing empirical data on devolatilization and char conversion. A model is developed to predict coal conversion (drying, devolatilization, and char conversion), coupling mass and heat transfer and accounting for primary and secondary fragmentation. The validation of the model yields satisfactory agreement between experimental and modelled mass loss curves and conversion rates during devolatilization and char conversion. It is shown that O_2/CO_2 mixtures give slightly longer devolatilization times and a decrease of char reactivity compared to O_2/N_2 mixtures.

14/00680 Effect of noncovalent bonds on the successive sequential extraction of Xianfeng lignite

Lei, Z. *et al. Fuel Processing Technology*, 2013, 111, 118–122.

In order to examine the effect of non-covalent bonds on the extraction yield of Xianfeng lignite (XL), XL is subjected to N-methyl-2-pyrrolididinone (NMP) extraction, acid treatment, and subsequent successive extraction with NMP, 1-butyl-3-methyl-imidazolium tetrafluoroborate ([Bmim]BF_4) and 1-butyl-3-methyl-imidazolium chloride ([Bmim]Cl) at 200 °C. The extraction yields in each solvent and step are investigated, respectively. The residues and extracts obtained in each step are characterized by Fourier transform infrared spectra. The results show that there are only small amount of the thermally induced relaxation of the aggregate structure of XL during NMP extraction. Furthermore acid treatment significantly increases the extraction yield of XL with NMP about 41.4%, which results from the release of ionic cross-links. [Bmim]BF_4 and [Bmim]Cl can break the weak and strong hydrogen bands in lignite, respectively. The extraction yield of XL is strongly dependent on non-covalent interactions, such as ionic cross-links and hydrogen bonds.

14/00681 Numerical simulation of lignite drying in a packed moving bed dryer

Zhang, K. and You, C. *Fuel Processing Technology*, 2013, 110, 122–132.

A numerical model was developed for the lignite drying process in a packed moving bed dryer based on governing equations and the lumped drying rate correlation of a single lignite particle. The lumped drying rate correlation incorporated into the packed state drying model was evaluated by comparing both experimental and calculated results for the convective drying of a single particle. The drying model for the packed fixed bed was established and verified by two kinds of lignite particle experiments and then used to examine the lumped drying rate correlation and heat transfer correlation incorporated into the packed state drying model. The simulations closely matched the experimental results for the average weight loss rate and gas temperature. The developed models can be used to predict the drying process in a packed moving bed. The lignite drying behaviour in the packed moving bed was simulated and the effects of the operating parameters on the drying process were analysed with the developed numerical model. The parameters included drying gas velocity, lignite particle size, lignite particle moving velocity and lignite particle stack height.

14/00682 The effect of supercritical water on coal pyrolysis and hydrogen production: a combined ReaxFF and DFT study

Zhang, J. *et al. Fuel*, 2013, 108, 682–690.

The reaction mechanism of coal pyrolysis and hydrogen production in supercritical water (SCW) was investigated using the molecular dynamic simulations via the reactive force field (ReaxFF) method combined with the density functional theory (DFT) method. The calculations present that the water clusters in SCW weaken the C–C bonds in aromatic rings, thus the C(ring)–C(ring) bond cracking energy decreases as much as 287.3 and 94.6 kJ/mol compared with that in pure coal pyrolysis and in coal pyrolysis in vapour state, respectively. After the aromatic rings break into small cyclic structures, such as quaternary rings and ternary rings, the water clusters in SCW further weaken their C–C ring bonds to induce the small cyclic rings to open. During this process, the water clusters (without any radicals) in SCW turn into H radical-rich water clusters after providing OH radicals to the cyclic rings. This is the main source for the production of hydrogen molecules in SCW–coal system. The combination of H radicals produced by coal with water clusters in SCW is another pathway which forms H radical-rich water clusters. Under the catalysis of water molecules or clusters, H radical-rich water clusters decompose into H_2 and OH radicals. These OH radicals further bind with coal intermediates and result in the breaking of coal intermediates into smaller products. Therefore, the cooperative effects between SCW and coal form a virtuous circle, which greatly enhances the reaction rate of coal gasification, promotes the production of small molecules, and increases the yield of hydrogen.

Transport, storage

14/00683 Prediction of coal stockpile autoignition delay time using micro-calorimeter technique

Zhao, X. *et al. Fuel Processing Technology*, 2013, 110, 86–93.

Spontaneous ignition of coal is one of the major challenges faced by coal industries, which results in a great loss and energy wastage. To evaluate the thermal behaviour of coal powder and predict the autoignition delay time (AIDT) of coal stockpile, a C80 micro-calorimeter was employed to detect the thermal behaviour of coal at elevated temperature. The reaction heat, reaction order, frequency factor and activation energy of coal were obtained from the experimental data. Based on the Semenov model, the self-heating oxidation temperature and temperature of no return were calculated for the 25 kg coal stockpile. Assuming that the coal stockpile is under quasi adiabatic conditions, its AIDT was predicted and compared with the experimental result. The comparison indicates that the micro-calorimeter technique is a useful way to access the safety of coal stockpile, which can be widely used in large-scale coal storage and transportation.

Economics, business, marketing, policy

14/00684 Deregulation, vertical unbundling and the performance of China's large coal-fired power plants

Zhao, X. and Ma, C. *Energy Economics*, 2013, 40, 474–483.

In 2003, China's integrated electricity utility – the State Power Corporation (SPC) – was unbundled and dismantled into five generation groups and two grid companies in an effort to increase competition and improve efficiency. This study considers the impact of this deregulation reform on the operational efficiency for a balanced panel of 34 large power plants for the period 1997–2010. It was found that on average these power plants have converged to the technological frontier over the sample period. Controlling for substantial heterogeneity in the technical profile, it was also found that the unbundling reform has boosted productivity of China's large thermal power plants; however, the presumably differential impacts of the reform on the previously SPC-managed power plants and the independent power producers in the sample are insignificant.

14/00685 Market-driven coal prices and state-administered electricity prices in China

Liu, M.-H. *et al. Energy Economics*, 2013, 40, 167–175.

This paper analyses how the Chinese government adjusts electricity prices for both industrial and residential users in response to changes in coal prices using an asymmetric error correction model. The results show that there is a long-term relation between the coal price and electricity prices but the relationship is weak especially for residential pricing. In the short run, electricity prices are adjusting faster upwards than downwards. Price adjustment towards long-run equilibrium is faster for residential users upwards than downwards. On the other hand, no evidence was found of asymmetric equilibrium adjustment in the electricity price for industrial use. The weak long-term relationship reflects the rigidity in electricity pricing and government's reluctance to subject end users to fluctuations of raw materials cost shifts.

14/00686 The environmental Kuznets curve and the role of coal consumption in India: cointegration and causality analysis in an open economy

Tiwari, A. K. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 519–527.

This study investigates the dynamic relationship between coal consumption, economic growth, trade openness and CO_2 emissions in case of India. In doing so, the Narayan and Popp structural break unit test is applied to examine the order of integration of the variables. The long-run relationship between the variables is tested by applying the autoregressive-distributed lag bounds testing approach to cointegration developed earlier. The results confirm the existence of cointegration for the long run between coal consumption, economic growth, trade openness and CO_2 emissions. The empirical exercise indicates the presence of environmental Kuznets curve in the long run as well as in the short run. Coal consumption as well as trade openness contributes to CO_2 emissions. The causality analysis reports the feedback hypothesis between economic growth and CO_2 emissions and same inference is drawn between coal consumption and CO_2 emissions. Moreover, trade openness Granger causes economic growth, coal consumption and CO_2 emissions.

Derived solid fuels

14/00687 Effect of aerosol loading on breakthrough characteristics of activated charcoal cartridges

Kuo, Y.-M. *et al. Journal of Aerosol Science*, 2013, 55, 57–65.

Charcoal cartridges are commonly employed to provide protection against a wide range of organic vapours at workplace owing to their excellent adsorption. In practical situations, not only organic vapours but also aerosol particles may exist in the workplace atmosphere. Focusing on aerosol particles, this study aimed to evaluate the effect of aerosol loading on both sorption capacity and breakthrough time of activated charcoal. Polydisperse corn oil aerosols with a mode of 0.2 μm and monodisperse acrylic powder of 0.15 and 10 μm were generated to load the test activated charcoal separately for conducting vapour sorption experiments. For liquid aerosol loading tests, the sorption capacities reduced by 14%, 38% and 46% and the 10% breakthrough times were shorten by 14%, 28% and 75% after loading 0.06, 0.14 and 0.25 g of corn oil aerosols per gram charcoal, respectively. For charcoal loaded with solid aerosols, the sorption capacity remained unchanged whereas the 10% breakthrough times were reduced by 26%, 27% and 35% after loading 0.019, 0.027 and 0.029 g of 0.15 μm acrylic powder per gram charcoal, and by 5%, 43% and 44% after loading 0.074, 0.13 and 0.18 g of 10 μm acrylic aerosols per gram charcoal, respectively. It was concluded that the breakthrough characteristics were affected by aerosol loading and the sorption capacity of activated charcoal can only be reduced by the loading of liquid aerosols. For the use of gas respirators with activated charcoal cartridges, it should be noted that the service life of the charcoal cartridges could be shortened due to aerosol loading in a work environment, from the perspective of respiratory protection.

14/00688 Formation of coke during the pyrolysis of bio-oil

Wang, Y. *et al. Fuel*, 2013, 108, 439–444.

Bio-oil from the pyrolysis of biomass can be upgraded into high quality liquid biofuels or utilized as a feedstock to boilers and gasifiers. The coke formation is a particularly serious problem for the upgrading of bio-oil as well as the direct utilization of bio-oil. The effects of bio-oil chemical composition on the coke formation are keys to the understanding of the mechanism of coke formation. A bio-oil sample produced from the fast pyrolysis of mallee wood at 500 °C and the lignin-derived oligomers separated from the bio-oil were pyrolysed in a two-stage fluidized-bed/fixed-bed reactor at temperatures between 250 and 800 °C. In addition to the quantification of coke yield, UV-fluorescence spectroscopy was used to trace the formation and evolution of aromatic ring systems during pyrolysis. The results indicate that both water-soluble and water-insoluble bio-oil fractions can form coke even at very low temperatures. The interactions among the species derived from cellulose/hemicellulose and lignin, especially the interactions involving their oligomers, are important to the observed coke yield, especially at low temperatures.

14/00689 Investigation on design parameters of single-walled carbon nanotube reinforced nanocomposites under impact loads

Khalili, S. M. R. and Haghbin, A. *Composite Structures*, 2013, 98, 253–260.

Multi-scale material modelling is applied to investigate the effect of major design parameters of reinforcing agents in single-walled carbon nanotube (SWCNT) reinforced nanocomposites in impact loads. The influence of diameter, chirality and volume fraction (VF) of SWCNTs on impact behaviour of different representative volume elements (RVEs) of nanocomposites is studied. SWCNTs are modelled through beam elements in space frame structures in finite element modelling (FEM) software based on their atomic structures in molecular mechanics. The RVEs are composed of various modelled SWCNTs embedded in an elastic medium as polymeric matrix. The various RVEs are exposed to a tensile impact load and the obtained responses are analysed to evaluate the effective design parameters of SWCNTs in the nanocomposite structures. The results in the form of strain energy density and axial strain oscillations of RVEs in a time period after impact demonstrate a great improvement in the impact behaviour of nanocomposites due to adding SWCNTs in matrix. Applying SWCNTs with smaller diameter in RVEs causes a better impact strength in nanocomposites. In design procedure of nanocomposites subject to the impact loads, it is better to concentrate on the size and the volume fraction of applied carbon nanotubes instead of their chirality.

14/00690 Optical ignition of nanoenergetic materials: the role of single-walled carbon nanotubes as potential optical igniters

Kim, J. H. *et al. Combustion and Flame*, 2013, 160, (4), 830–834.

This study demonstrates the effective optical ignition of nanoenergetic materials (nEMs) by adding single-walled carbon nanotubes (SWCNTs) as an optical ignition agent into an nEM matrix composed of Al/CuO nanoparticles (NPs). The measured burn rate and pressurization rate of SWCNT (optical igniter)-Al NP (fuel)-CuO NP (oxidizer) composites were found to attain maximum values of ~240 m/s and ~5.9 ± 0.8 psi/μs, respectively, in the case of SWCNT (1 wt%)-nEM composites. As the amount of SWCNTs added into the nEM matrix was further increased (i.e. SWCNT > 2 wt%), both the burn rate and the pressurization rate of the as-prepared SWCNT-nEM composites decreased significantly. This was because the large amount of SWCNTs in the nEM matrix increased the heat dissipation through the SWCNT agglomerates, so that the temperature increase in the SWCNT-nEM composite was limited, thus hindering the oxidation and subsequent ignition of the nEMs. This suggests that the remote optical ignition and controlled-explosion reactivity of nEMs can be performed by incorporating SWCNTs as a potential optical ignition agent with nEMs.

14/00691 Porous structure and morphology of granular chars from flash and conventional pyrolysis of grape seeds

Jimenez-Cordero, D. *et al. Biomass and Bioenergy*, 2013, 54, 123–132.

This work studies the influence of the operating conditions used in the pyrolysis of grape seeds on the morphology and textural properties of the chars resulting. Flash and conventional ($283\,\mathrm{K\,min^{-1}}$ heating rate) pyrolysis have been used within a wide range of temperature (300–1000 °C). The effect of a pretreatment for oil extraction has also been studied. The porous structure of the chars was characterized by adsorption of N_2 at 77 K, Ar at 77 and 87 K, and CO_2 at 273 K and mercury intrusion porosimetry. The morphology was analysed by scanning electron microscopy. All the materials prepared revealed an essentially microporous structure, with a poor or even negligible contribution of mesopores. Increasing pyrolysis temperature led to higher specific surface areas and lower pore size. The highest specific surface area values occurred within 700–800 °C, reaching up to 500 $m^2 g^{-1}$ with pore sizes in the 0.4–1.1 nm range. No significant morphological changes were observed on carbonization so that the resulting chars were granular materials of similar size than the starting grape seeds. The hollow core structure of the chars, with most of the material allocated at the periphery of the granules can help to overcome the mass transfer limitations of most common (solid or massive) granular activated carbons. The chars showed a good mechanical strength during attrition tests. These chars can be potential candidates for the preparation of granular carbons molecular sieve or activated carbons raw materials.

14/00692 The effects of kraft lignin additives on wood fuel pellet quality, energy use and shelf life

Berghel, J. *et al. Fuel Processing Technology*, 2013, 112, 64–69.

In 2011, the total consumption of pellets in Sweden amounted to 1.9 million tons, which represents an energy value of 9 TWh. The pellets are used in large-scale as well as in small-scale applications, and increased demands on pellet quality are likely to force pellet producers to improve on the pellet properties. One way of increasing pellet quality is by using additives. The purpose of this paper, therefore, is to examine kraft lignin as an additive. Pellets were produced in a small industrial pellet press located at Karlstad University, Karlstad, Sweden, and 1–4% of kraft lignin was added to the pellets. The results indicate that the addition of an increased amount of kraft lignin to the pellets increases their mechanical durability and their lengths. The results also indicate that dry kraft lignin yields pellets with higher durability as compared to wet kraft lignin. The energy demand was unaffected by the increased use of kraft lignin. The general results presented in this paper are useful for producers of lignin, pellet producers and end-users of pellets, who are interested in developing their products and/or improving the production processes.

14/00693 Utilization of wood biomass char in a direct carbon fuel cell (DCFC) system

Ahn, S. Y. *et al. Applied Energy*, 2013, 105, 207–216.

Wood biomass char was used in a direct carbon fuel cell (DCFC) as an alternative fuel. This has many advantages because the DCFC is a high-efficiency system and wood biomass is a carbon-free and regenerative material. Several analytical techniques were employed to analyse the characteristics of three fuels, their effects on the cell's performance, and the electrochemical reactions between the fuels and the electrolyte in the system. The morphological and textural characteristics of biomass char were similar to those of two types of coal used as fuels for a DCFC system in spite of the char's significantly lower carbon content. A practical evaluation of the fuels used in the DCFC system was conducted, and when using the biomass char, the maximum power density was 60–70% that of the corresponding value for coal under the same conditions. The performance of the biomass char fuel was improved by stirring. The possibility of its practical application was also discussed.

02 LIQUID FUELS

Sources, properties, recovery

14/00694 Determination of solubility parameters of oils and prediction of oil compatibility

da Silva Ramos, A. C. *et al. Journal of Petroleum Science and Engineering*, 2013, 102, 36–40.

Models and parameters applied to evaluate stability of asphaltenes in oils and mixtures of oils assume that at the solubility limit of asphaltenes there is little variation in the solubility parameter (flocculation parameter), which may be used to determine the Hildebrand solubility parameter of oils. This study presents an alternative methodology to determine solubility parameters of oils and a model for compatibility prediction. The methodology has been shown efficacious in determining the solubility parameters of oils even in those oils with low content of asphaltenes and a high amount of particles in suspension, where other methods had not yielded a good performance. The calculated solubility parameters were used to predict the oil compatibility and the results correlate well with experimental data.

14/00695 Optimal producer well placement and production planning in an oil reservoir

Tavallali, M. S. *et al. Computers & Chemical Engineering*, 2013, 55, 109–125.

Most of the available literature on optimal well placement has employed numerical simulators in a black box manner linked to an external search engine. The authors formulate the contents of that box inside a mixed integer non-linear programming model for optimal well placement. They then provide a unified model that integrates the subsurface, wells, and surface levels of an upstream production project. It links the production plan with the aforementioned elements, and economics and market. This results in a complex spatiotemporal mixed integer non-linear model, for whose solution the authors modify and augment an existing outer approximation algorithm. The model solution provides the optimal number of new producers, their locations, and optimal production plan over a given planning horizon. To the authors' knowledge, this is the first contribution that uses mathematical programming in a real dynamic sense by honouring the constituent partial differential equations.

14/00696 Residual stress measurements in a ferritic steel/In625 superalloy dissimilar metal weldment using neutron diffraction and deep-hole drilling

Skouras, A. *et al. International Journal of Pressure Vessels and Piping*, 2013, 101, 143–153.

This paper reports the use of non-invasive and semi-invasive techniques to measure the residual stresses in a large dissimilar weldment. This took the form of a butt weld between two sections of a P92 steel pipe, joined using an In625 welding consumable. Residual stress measurements have been carried out on the 30 mm thick welded pipe using the deep-hole drilling technique to characterize the through wall section residual stress distribution for the weld metal, HAZ and parent material. In addition, neutron diffraction measurements have been carried out within the weld zone. Diffraction patterns presented a high intensity and sharp peaks for the base P92 steel material. However measurements in the weld superalloy material were proven problematic as very weak diffraction patterns were observed. A thorough examination of the weld material suggested that the likely cause of this phenomenon was texture in the weld material created during the solidification phase of the welding procedure. This paper discusses the challenges in the execution and interpretation of the neutron diffraction results and demonstrates that realistic measurements of residual stresses can be achieved, in complex dissimilar metal weldments.

14/00697 Structural setting of the Adriatic basin and the main related petroleum exploration plays

Casero, P. and Bigi, S. *Marine and Petroleum Geology*, 2013, 42, 135–147.

Most of the oil and gas resources located within the Adriatic domain are genetically linked to the flexure of the Adria continental margin and to the evolution of the Apennines fold and thrust belt. The source rocks contained in the pre-flexure epi-continental successions reached the maturity window during the flexural subsidence or, alternatively, the flexural accommodating siliciclastic flysch themselves generated and stored hydrocarbons. The petroleum exploration plays of the Adriatic domain are tentatively classified in this paper, according to their geological evolution with respect to the Apennines fold and thrust belt. The description of the geological evolution of these structures and related petroleum plays are described, including plays set in undeformed or poorly deformed foreland areas. A new isochrones map showing the structural setting of the substratum at the level of the Fucoidi Fm. is presented. Several different groups of structures can be recognized in the Adriatic domain, that can be connected to the final phases of deformation of the Apennines, or to the interaction with the Dinarides fold and thrust belt front to the east.

14/00698 The dominant mechanism of enhanced heavy oil recovery by chemical flooding in a two-dimensional physical model

Zhou, X. *et al. Fuel*, 2013, 108, 261–268.

The dominant mechanism of enhanced heavy oil recovery by chemical flooding is studied by conducting various chemical slug injections in a two-dimensional physical model. In this study, a total of seven single-chemical-slug tests and another seven two-chemical-slug tests are conducted to test the contribution of alkaline, surfactant, polymer, and their combinations to enhanced heavy oil recovery. The relationship between the tertiary oil recovery and the pressure drop of the seven single-slug floods is analysed, and it is discovered that the two have a good correlation. Comparison of the tertiary oil recoveries of different chemical slug tests shows that the improved waterflood for the heavy oil used in this study is mainly due to the reduction of water mobility. The results of two-chemical-slug tests show that after regular alkaline/surfactant/polymer flooding, the second polymer slug injection can recover more oil, if a water slug injection is applied between the two chemical slugs.

14/00699 Toward reservoir oil viscosity correlation

Hemmati-Sarapardeh, A. *et al. Chemical Engineering Science*, 2013, 90, 53–68.

Oil viscosity plays a key role in reservoir simulation and production forecasting, as well as planning thermal enhanced oil recovery methods and these make its accurate determination necessary. In this communication, the most frequently used oil viscosity correlations are evaluated using a large databank of Iranian oil reservoirs which were measured using a rolling ball viscometer (Ruska, series 1602). To evaluate the performance and accuracy of these correlations, statistical and graphical error analyses have been used simultaneously. Three of the most accurate correlations for each region, including dead oil viscosity, viscosity below bubble point, viscosity at bubble point and the under-saturated oil viscosity, are recommended for Iranian oil reservoirs. In the last step, four correlations are developed for Iranian oil reservoirs which have simplified functional format. Furthermore, the input data of the latter correlations are those ones that are easily measured in oil fields. The ranges of data used to develop these new correlations cover almost all Iranian oil reservoirs' PVT data and consequently they could be reliable for prediction of other Iranian oil reservoirs viscosity. These new correlations are consistent across a wide range of parameters and offer increased accuracy than previously published correlations for viscosity prediction of Iranian oil reservoirs.

14/00700 Viscoelastic properties and constitutive modelling of bitumen

Behzadfar, E. and Hatzikiriakos, S. G. *Fuel*, 2013, 108, 391–399.

This study considers the viscoelastic behaviour of bitumen and identifies an appropriate and suitable constitutive equation to describe its rheological behaviour. First, the generalized Maxwell model has been utilized to represent the relaxation modulus of bitumen and found to be in excellent agreement with experimental data over a wide range of temperatures (−30 to 90 °C). Furthermore, the time–temperature superposition principle was found to be applicable over this temperature range. The K-BKZ constitutive equation has been shown to represent accurately the rheological properties of bitumen. Analysis of experimental results revealed that either the Papanastasiou or the Marucci form of the damping function can be used in the K-BKZ constitutive equation. Moreover, the damping function was found to be independent of temperature (0–50 °C).

Transport, refining, quality, storage

14/00701 A composite inhibitor used in oilfield: MA-AMPS and imidazoline

Gu, T. *et al. Journal of Petroleum Science and Engineering*, 2013, 102, 41–46.

Polyepoxysuccinic acid (PESA) is a new kind of biodegradable-scale inhibitor. A scaling-corrosion inhibitor composed of modified PESA and imidazoline is manufactured. Compound prescriptions of water treatment agents are screened by rotary coupon corrosion test and static anti-scaling method, respectively. The optimal ratio of corrosion and scale inhibitor has been found, and experimental result shows that the sifted prescription has excellent performance of corrosion and scale inhibition.

14/00702 A new method for online flow regime monitoring in bubble column reactors via nuclear gauge densitometry

Shaikh, A. Al-Dahhan, M. *Chemical Engineering Science*, 2013, 89, 120–132.

In the current work, nuclear gauge densitometry (NGD), which is commercially available and industrially used for liquid/slurry level measurement and control, has been employed to identify fingerprints of the prevailing hydrodynamic flow regime. Experiments were performed using an air–water system in 0.1012 m diameter and 1.2 m long bubble column at ambient pressure. The superficial gas velocities were varied from 1 to 12 cm/s with an interval of 0.5 cm/s near transition region. The flow regime boundaries were defined using the conventional methods of flow regime demarcation such as the change in the slope of the overall gas holdup and the drift flux plot. The obtained photon counts history was subjected to various time-series analyses. Based on the comparison with the results of conventional methods, objective flow regime identifiers for NGD were proposed. The obtained flow regime identifiers can be helpful for online flow regime monitoring in laboratory as well as industrial bubble column reactors.

14/00703 An analytical formula for elastic–plastic instability of large oil storage tanks

Yang, L. *et al. International Journal of Pressure Vessels and Piping*, 2013, 101, 72–80.

Assuming axisymmetric buckling and according to the adjacent equilibrium criterion, a buckling critical stress formula of a perfect tank wall is first obtained through analysis of elastic–plastic buckling carried out by J_2 plastic flow theory. Furthermore, combining the current tank seismic design standards and the results obtained in this paper, a new critical buckling stress formula of the tank wall is derived after correction for material plasticity by introducing a plasticity influence coefficient. Comparisons between the results obtained and those from the relevant formulas in the design standards of the USA, Japan, China and Europe are also performed. The research shows that under interaction of high hydraulic and axial compression, the material properties of the tank wall change rapidly, and the buckling strength of the tank wall also decreases rapidly. The relation between the tank wall buckling critical stress and the hydraulic pressure is similar to Rotter's semi-empirical formula. The results presented in this paper can provide technical support in further protection of large oil storage tanks.

14/00704 Analysis of lightning phenomena for underground petroleum pipeline system

Bhumkittipich, K. *et al. Energy Procedia*, 2013, 34, 148–158.

This analysis of lightning phenomenon for an underground petroleum pipeline and its protection has shown that the lightning instantaneous potential at the distance along the pipeline will be higher when the pipeline length is increased. This is due to its inductance directly varying according to pipeline length and the instantaneous current tending to decrease as its length increasing. When considering the impedance from the pipeline and corrosion protection circuit cable, it was found that both instantaneous potential and current are higher than the safety values of the devices and are enough to cause damage to corrosion protection devices. The result of this protection simulation has shown that instantaneous potential can be limited to less than 1500 V by following BS 60950. Therefore the correct lightning protection equipment will help to reduce damage to the petroleum transportation industry from lightning strikes.

14/00705 Boosting the gasoline production via a novel multifunctional Fischer–Tropsch reactor: simulation and optimization

Bayat, M. and Rahimpour, M. R. *Journal of Natural Gas Science and Engineering*, 2013, 11, 52–64.

The multifunctional reactor has been recognized as one of the most promising configurations for simultaneous production of gasoline and hydrogen; as well as stabilizing atmospheric greenhouse gases. This paper focuses on mathematical modelling and optimization of a novel multifunctional reactor in order to enhance the production of gasoline and reduce CO_2 and CH_4 emissions. Fischer–Tropsch synthesis was carried out in exothermic side and supplied the necessary heat for the benzene synthesis reaction. The proposed reactor configuration consisted of two catalytic fixed beds separated by the solid wall and also two Pd/Ag membranes, one was used for ultrapure hydrogen production from the endothermic side and the subsequent was applied in order to selectively add hydrogen to the exothermic side. A one-dimensional, steady-state heterogeneous model and the differential evolution method, as a strong and powerful optimization method, are applied to simulate and optimize the proposed reactor configuration. The results of the optimized multifunctional reactor (OMR) represent a 40.91% enhancement in the yield of gasoline in comparison with conventional Fischer–Tropsch reactor (CR). Moreover, a 75% and 34.46% decrease in the yield of methane and carbon dioxide, respectively, was obtained. A favourable temperature profile along the reactor length of OMR was achieved in comparison with CR.

14/00706 Design of hybrid distillation/melt crystallisation processes for separation of close boiling mixtures

Micovic, J. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 16–24.

Hybrid separations combining distillations and crystallizations have a significant potential for process intensification. To address the large number of degrees of freedom in the design of hybrid separations, a three-step approach is utilized. However, it can only be applied if all parameters for the rigorous modelling of crystallization and cost functions are known a priori, which is often not the case. This paper proposes a four-step design method which can be applied in early process development stages when not all model parameters are available. In the first step, different process variants are generated. In the second step, the variants are evaluated using rigorous models, wherein the unknown model parameters are varied to quantify their influence on the process performance. If hybrid separations appear to be compatible, experiments are performed to determine the unknown parameters in the third step. In the last step, an optimization is performed to find the optimal process, when necessary in dependence of unknown cost parameters. The developed tools and the feasibility of the approach are illustrated with the separation of a binary mixture of long-chain isomeric aldehydes.

14/00707 Effect of carbon support on Fischer–Tropsch synthesis activity and product distribution over Co-based catalysts

Fu, T. *et al. Fuel Processing Technology*, 2013, 110, 141–149.

The ordered mesoporous carbon (CMK-3) was prepared using SBA-15 as template and sucrose as carbon source. Cobalt catalysts supported on CNTs, CMK-3 and AC were prepared by incipient wetness. Their physical properties, morphologies and Fischer–Tropsch synthesis (FTS) activities were assessed. It was found that Co_3O_4 particles mainly dispersed inside the tubes (or pores) of Co/CNTs and Co/CMK-3 but outside the pores of Co/AC. Co_3O_4 particle size depended closely on the support structure. After H_2 reduction, the three catalysts had a similar cobalt particle size. The cobalt particle size of Co/CNTs was maintained well due to the special confinement effect of CNTs. CNTs were more stable at high temperature in H_2 atmosphere than CMK-3 and AC and the reduction degree of Co/CNTs was higher than the other two catalysts. The good crystallized graphitic structure facilitated the electron transfer between the cobalt and CO molecules on Co/CNTs. So Co/CNTs had a better FTS performance than Co/CMK-3 and Co/AC catalysts. Carbon support structure influenced the C_{5+} selectivity, C_{5+} hydrocarbon distribution and CO turnover frequency. Furthermore, a positive relationship existed between C_2–C_4 olefin/paraffin ratio and C_{5+} selectivity. High olefin content and low space velocity benefit the heavy hydrocarbon production.

14/00708 Long term storage of biodiesel/petrol diesel blends in polyethylene fuel tanks

Thompson, M. R. *et al. Fuel*, 2013, 108, 771–779.

This paper explores the long-term effects that an ageing biodiesel fuel blended with low sulfur diesel fuel at concentrations of 0%, 15%, 50%, 85%, and 100% (v/v) can have on polyethylene materials. Rotationally moulded fuel tanks made of linear low density polyethylene or cross-linked polyethylene were used to appropriately mimic the storage environment of fuels, though the study also considered immersed polymer specimens as this test approach is more commonly reported on in the literature. The extent of oxidation for the fuels was monitored by determination of its peroxide value and acid number over time, with both values being consistently higher for blends with higher biodiesel content. Storage at 80 °C for up to 56 days resulted in significant oxidation of the fuel while testing up to 380 days at 23 °C produced no change in peroxide or acid concentration. The change in mechanical properties for the polyethylenes due to fuel was determined by tensile testing. Comparing the tensile data to the oxidation species in the stored fuels revealed that noted mechanical losses did not correspond with higher concentration of hydroperoxides or acid species but rather occurred as a result of fuel absorption. No difference was found in this regards between the two polyethylene species.

14/00709 Monitoring the liquid/liquid extraction of naphthenic acids in Brazilian crude oil using electrospray ionization FT-ICR mass spectrometry (ESI FT-ICR MS)

Colati, K. A. P. *et al. Fuel*, 2013, 108, 647–655.

Although the term 'naphthenic acids' was originally used to describe acids that contain naphthenic rings, today this term is used in a more general sense and refers to all cyclic, acyclic, and aromatic acids in crude oil. In crude oil, naphthenic acids exist as a complex mixture of compounds with broad polydispersity with respect to both molecular weight and structure. Recently, there has been increasing interest in acidic fractions in crude oil because of the corrosion problems that these compounds cause during oil refinery. This corrosion is associated with the total acid number (TAN). However, it has been argued that there is no clear correlation between the TAN and the level of corrosion. Herein, naphthenic acids were extracted from two crude oil samples (TAN = 4.95 and 3.19 mg KOH g^{-1}) using liquid/liquid extraction with alkaline solutions at three different pHs (pH 7, 10 and 14), thus evaluating the efficiency and selectivity among different acidic extraction methods to prevent future corrosion processes in petroleum industry such as regions of the refineries working. The original oil samples and their naphthenic acidic fractions and residues (washed oil from the acidic extraction) were analysed using negative-ion electrospray ionization (ESI) Fourier transform ion cyclotron mass spectrometry (FT-ICR MS) and Fourier transform infrared spectroscopy (FTIR). The TAN and sulfur content were also determined. The authors observed a decreasing TAN in the original oil with increasing pH ($7 \rightarrow 14$), reaching a value of almost zero at pH 14. Consequently, an intense band at approximately 1700 cm^{-1} was observed for the naphthenic acidic fraction. Fractions produced ESI(−)-FT-ICR MS spectra with average molecular weight distribution, M_w, and m/z values ranging from m/z 200–350 and $M_w = 270$ (for pH 7) to m/z 200–650 and $M_w = 390$ (for pH 14). Therefore, the acidic extraction method at pH 14 was more efficient and the ESI FT-ICR MS analysis reveals that the most abundant naphthenic acids are those with short alkyl chain lengths ($< C_{44}$) and DBE = 3–4. These compounds were responsible for the TAN observed for the original oil.

14/00710 Oxidative desulfurization of simulated gasoline catalyzed by acetic acid-based ionic liquids at room temperature

Liang, W. *et al. Fuel Processing Technology*, 2013, 109, 27–31.

A series of acetic acid-based ionic liquids (ILs) were synthesized and used for oxidative desulfurization as both a catalyst and an extractant. The practical and orthogonal experiments showed that $[Otbim]^+CH_3COO^-$ containing eight-carbon side chain has the best catalytic activity. A total of 87.5% of thiophene in the model oil was removed under the optimal conditions of oxidation temperature at 70 °C, oxidation time of 180 min, simulated oil dosage of 10 ml, and ILs/H_2O_2 volume ratio of 1 : 1.1. Meanwhile, the ILs could be recycled five times without any apparent loss of the catalytic activity.

14/00711 Prediction of minimum miscibility pressure in oil reservoirs using a modified SAFT equation of state

Fazlali, A. *et al. Fuel*, 2013, 108, 675–681.

In a miscible gas flooding to heavy oil reservoirs, multiple-contact miscibility between injected gas and reservoir oil can be achieved at pressure greater than a minimum value that is referred to minimum miscibility pressure (MMP). This research includes two parts: first, modification of simplified statistical associating fluid theory (SAFT) (*m*SSAFT) equation of state (EOS) is derived to describe vapour–liquid equilibrium calculations and second, prediction of MMP according to forward multiple contact model is done. With respect to objective function, adjustable parameters of SSAFT and *m*SSAFT were obtained for 21 pure compounds. Comparison of AAD% of the results of *m*SSAFT, SSAFT and PR EOSs in predicting vapour pressure, liquid density and enthalpy shows that *m*SSAFT is the most accurate of all. Also, accuracy of these three EOSs for various mixtures has been verified, and the results confirm the reliability of *m*SSAFT EOS. At last, AAD% of MMP prediction by mentioned EOSs (*m*SSAFT is 2.20%, SSAFT is 3.25% and Peng–Robinson is 4.13%) proves that Statistical EOSs are more reliable than cubic EOS in modelling MMP.

14/00712 Study on flow pattern maps in hilly-terrain air–water–oil three-phase flows

Huang, S. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 158–171.

Although three-phase flows are often encountered in offshore petroleum engineering, there have been only a few comprehensive studies on flow pattern maps. In this study, an experimental programme was carried out to obtain flow pattern maps in hilly-terrain air–water–oil three-phase flows. Two elbows, including two symmetrical inclined pipes, were used at the peak and the valley respectively, with an inclination angle of 0–30°. The test section was made of transparent acrylic resin, with a total length of 10 m and an inner diameter of 40 mm. The superficial velocities were 0.01–15, 0.01–2 and 0.01–2 m/s for air, water and oil, respectively. By using a high-speed camera and a single-wire capacitance probe, the authors recorded the flow processes and measured the water layer height in the pipe, and further identified different flow patterns. Similar to the flow patterns in horizontal pipes, 11 typical flow patterns were observed in the present study. However, the ranges in the flow pattern maps were extended for intermittent flow in uphill pipes, and also for stratified flow in downhill pipes. When each superficial velocity was low enough, elbows, causing accumulation at the peak and the valley of the hilly-terrain system, determined the flow pattern in the downstream pipes, and resulted in different flow patterns in the uphill and downhill pipes. Nevertheless, when superficial gas velocity was high enough, exceeding 10 m/s, all the flows tended to be annular along the whole hilly-terrain pipes. It may be appropriate to simplify the air–water–oil three-phase flow into gas–liquid two-phase flow, where water fraction had an effect on oil–water distribution and changes the viscosity of the liquid mixture. As a result, water fraction was considered as a secondary factor to determine flow patterns when compared with pipe structures and superficial velocities.

14/00713 Upgrading of heavy crude oils: Castilla

Carrillo, J. A. and Corredor, L. M. *Fuel Processing Technology*, 2013, 109, 156–162.

Oil resources similar to WTI and Brent crude oils are dwindling, so heavy and extra-heavy crude oils, and bitumen must be used to meet the growing demand for fuels. The vast majority of the world's refineries are not suitable for processing these types of feed stock, so upgrading processes are required to make synthetic crude oils from those resources compatible with the equipment installed. By its viscosity Castilla crude oil is not classified as an extra-heavy crude oil, as even on surface it flows. However, it has 45.6 wt% of vacuum bottoms and high concentrations of Conradson carbon (CCR of 34 wt%) and metals (nickel and vanadium content of 928 ppm) within it. This paper presents various alternatives for the upgrading of the crude Castilla, using as raw material crude oil free of lights (199 °C$^+$), reduced crude (370 °C$^+$) and vacuum bottoms. The technologies used in the studied scheme were visbreaking (VBK), delayed coking (DC), solvent deasphalting (DAF), hydrotreating and distillation. The studies were conducted at pilot plant scale and the analysis of the products was done using standard techniques such as ASTM. Among the outstanding results is the operational scheme of the vacuum bottoms visbreaking, but this is not a typical visbreaking process because the coke production was 8.2 wt%. A furnace with some characteristics of a DC furnace, and a pair of soakers that function as coking drums should be used to avoid coke deposition within the internal walls of the coils. This is an innovative technology that sits between visbreaking and delayed coking.

Economics, business, marketing, policy

14/00714 A heuristic batch sequencing for multiproduct pipelines

MirHassani, S. A. and BeheshtiAsl, N. *Computers & Chemical Engineering*, 2013, 56, 58–67.

Multiproduct pipelines are designed to transport refined petroleum products from major sources to distribution centres. Moreover, the existence of large, complex and world wide spread businesses leads to a complex system in which distribution can be seen as one of the key areas that needs to be efficiently and effectively managed. The system reported in this paper was composed of an oil refinery, a multiproduct pipeline connected to a storage tank farm that received large amounts of oil derivatives. In this work, a heuristic method was proposed for scheduling a real life system. The output was an operational programme for running a pipeline efficiently in a given time horizon while considering almost all practical restrictions. The algorithm was able to achieve a near-optimal solution in a reasonable time. The approach was successfully applied to a number of pipelines including a real-life problem. The data and experimental results were reported.

14/00715 A Lagrangean [Lagrangian] decomposition approach for oil supply chain investment planning under uncertainty with risk considerations

Oliveira, F. *et al. Computers & Chemical Engineering*, 2013, 50, 184–195.

This study presents a scenario decomposition framework based on Lagrangian decomposition for the multi-product, multi-period, supply investment planning problem considering network design and discrete capacity expansion under demand uncertainty. A risk measure is also considered that allows one to reduce the probability of incurring in high costs while preserving the decomposable structure of the problem. To solve the resulting large-scale two-stage mixed-integer stochastic linear programming problem, the authors propose a novel Lagrangian decomposition scheme, and compare different formulations for the non-anticipativity conditions. In addition, they present a new hybrid algorithm for updating the Lagrangian multiplier set based on the combination of cutting-plane, subgradient and trust-region strategies. Numerical results suggest that different formulations of the non-anticipativity conditions have a significant impact on the performance of the algorithm. Moreover, the authors observe that the proposed hybrid approach has superior performance in terms of faster computational times when compared with the traditional subgradient algorithm.

14/00716 Are the crude oil markets becoming more efficient over time? New evidence from a generalized spectral test

Zhang, B. *Energy Economics*, 2013, 40, 875–881.

This paper utilizes the newly developed method of a generalized spectral test to examine the weak-form efficiency of the main worldwide crude oil markets. The generalized spectral test, unlike other methods, can detect both linear and non-linear serial dependence in the conditional mean and allows for different forms of unknown conditional heteroscedasticity. By using a ‘rolling sample’ approach instead of an analysis of different time periods, the authors find that the efficiency of oil markets may depend on time periods. The main global crude oil markets reach weak-form efficiency in the long-term and the degree of efficiency of global oil markets changes over time. Among the oil markets examined in this study, the Brent and the WTI oil markets possess the highest efficiency levels, whereas the Daqing oil market has the lowest efficiency level. Apparent anti-synchronization is detected between the efficiency of Brent and WTI markets in recent years, whereas synchronization is found between the efficiency of Daqing and Dubai oil markets during the last decade.

14/00717 Crude oil, equity and gold futures open interest co-movements

Souček, M. *Energy Economics*, 2013, 40, 306–315.

The study is unique in its investigation of the co-movements between trading activity on the equity, crude oil, and gold futures market, proxied by open interest. It provides empirical evidence that stock and crude oil futures demand for hedging is positively related, but reacts negatively to sudden shocks in open interest on the other market. Furthermore, gold futures open interest reacts positively to shocks in the crude oil futures trading activity. The level of instantaneous linkage is related to external market conditions. During periods of unstable financial markets, the correlation between equity and energy futures open interest decreases, and the correlation of the open interest on the equity and gold futures market turns weak negative. This indicates hedging funds allocation toward gold market in periods of stock market uncertainty.

14/00718 Enhancing the value of offshore developments with flexible subsea tiebacks

Lin, J. *et al. Journal of Petroleum Science and Engineering*, 2013, 102, 73–83.

Many of the world’s largest and most profitable offshore oil and gas basins are reaching maturity and are declining in profitability. Most new discoveries tend to be smaller and present as fragmented and geographically dispersed reservoirs with substantial uncertainty concerning geology and marginal exploration costs. Many of these discoveries only make sense when considered as a set. This situation is compounded by large oil and gas price volatility and a very large combinatorial size of the design and operational decision space. Subsea tiebacks that connect new fields to existing production facilities are a means of extending the life and profitability of offshore facilities. The challenges of subsea tiebacks are both technical – they require connecting fields and facilities over large distances (>10 km) in deep water (>500 m) – and conceptual. It is not immediately clear where production facilities should be placed, how they should be sized, and in what sequence and when tiebacks should be put in place to optimize value. This paper presents a methodology that evaluates three kinds of flexibility as a means to mitigate uncertainty in subsea tiebacks: the ability to tie back new fields, the ability to expand the capacity of a central processing facility, and the dynamic allocation of processing capacity to the connected fields. The methodology uses an integrated mid-fidelity system model in conjunction with Monte Carlo simulation to identify potential platform design capacities and tieback phasing strategies under reservoir, facilities, and market uncertainties. The authors demonstrate the methodology on an offshore multiple-oilfield development patterned after a real case off the west coast of Africa. The results show that because of the concurrent presence of reservoir, facilities, and market uncertainties, implementing flexibility significantly increases, by as much as 76%, the expected net present value of the project compared to a traditional point-optimal inflexible design.

14/00719 Exergy analysis of the oil and gas processing on a North Sea oil platform a real production day

Voldsund, M. *et al. Energy*, 2013, 55, 716–727.

This study explores the applicability of exergy analysis as an evaluation and monitoring tool for the oil and gas processing on an offshore platform. A real production day on a particular North Sea platform is analysed. A process flowsheet is simulated using measured process data. The authors distinguished between temperature-based exergy, pressure-based exergy and the mixing part of the chemical exergy. It is shown that physical exergy in the material streams mainly is pressure-based exergy, and most exergy destruction is related to decrease or increase in pressure. The sub-processes with most destructed exergy are the production manifold (4600 kW), the recompression train (4150 kW) and the reinjection trains (10,400 kW). At this platform 260 kW of separation work is done, a considerable part is carried out in the compression trains in addition to the separation train. The specific power consumption is 179 ± 3 kWh/Sm^3 and the exergetic efficiency is 0.13 ± 0.02. The authors propose measures to decrease exergy destruction, and that exergy analysis should be taken into regular use by the oil and gas industry. This study serve as a showcase on how to do an exact analysis of an existing offshore platform using measured process data.

14/00720 From oil to consumer energy prices: how much asymmetry along the way?

Venditti, F. *Energy Economics*, 2013, 40, 468–473.

A longstanding question in macroeconomics is whether fuel prices react more to increases than to decreases of the price of oil. This paper analyses the response of weekly gasoline and gasoil prices to oil prices in the USA, the euro area and the four largest euro area countries (Germany, France, Italy and Spain) using non-linear impulse response functions and forecast accuracy tests. While for the USA both approaches point to the presence of asymmetries in the adjustment of retail prices, for the euro area the evidence is mixed.

14/00721 How does oil market uncertainty interact with other markets? An empirical analysis of implied volatility index

Liu, M.-L. *et al. Energy*, 2013, 55, 860–868.

The OVX crude oil volatility index, as a measure of oil market uncertainty and new volatility derivatives published by the Chicago Board Options Exchange during the 2008 global financial crisis, provides a direct prediction of the market's expectation for future 30-day crude oil price volatility. This paper investigates the short- and long-term cross-market uncertainty transmission implied by OVX and other important volatility indices which are VIX (stock market volatility index), EVZ (euro/dollar exchange rate volatility index) and GVZ (gold price volatility index). The results indicate that there are no strong long-run equilibrium relationships among these volatility indices, which indirectly verify the effectiveness of cross-market volatility portfolio strategy for risk hedge. Furthermore, OVX is significantly influenced by other ones, which indicates that investors' volatility expectation in the oil market become more sensitive to uncertainty shocks from other markets when the global economic situation is extremely unstable. Finally, impacts of interior and exterior uncertainty shocks on OVX are found to be positive and transient. And the significant short-term uncertainty transmission between oil and other major markets has been confirmed.

14/00722 Pricing option contracts on the strategic petroleum reserve

Murphy, F. and Oliveira, F. S. *Energy Economics*, 2013, 40, 242–250.

This study examines the pricing of option contracts on the strategic petroleum reserve (SPR) and consider how these can be used by both the government and refiners. The authors analyse the interaction between the call and put option contracts, taking into account the underlying game, in the infinite Markov decision process with discounting, explaining the relationship between the valuation of options on the SPR by refiners and the valuation of financial options on a marker crude in financial markets. They conclude that the values of both call and put options on the SPR increase with oil prices and decrease with total inventory. Furthermore, the analysis shows that a more active management of the SPR creates higher social welfare (although refiners profit less from inventories) and larger volatility in inventory profits, decreasing private investment in petroleum stocks.

14/00723 Quantifying the risk to crude oil imports in China: an improved portfolio approach

Ge, F. and Fan, Y. *Energy Economics*, 2013, 40, 72–80.

China's rapid economic development caused a sharp increase in crude oil demand. In 2011, China imported 254 million tons of crude oil in total, with its dependence on imported oil reaching 56.5%. This paper carries out a quantitative study on the risk of China's crude oil imports by establishing an assessment model which has two primary characteristics. First, the model not only uses portfolio theory to assess the risk to China's crude oil imports, taking into consideration the effect of the diversified sources of imports, but also introduces a correlation coefficient which considers the risks associated with importing oil from oversea sources. Second, the correlation between import prices and global oil prices is analysed with respect to each exporting country. The Ease of Doing Business Index grading system is introduced in order to represent the risk weight for each exporting country. Because of these improvements, the model provides operable methods for studying how global oil prices, import volumes, the diversification index, and the political and economic situation of the exporting countries affects China's crude oil import risks as well as offers a method for implementing optimal crude oil import strategies. It is concluded that China's crude oil import risks associated with the Middle East are not as precarious as researchers traditionally reported. Among countries in the Middle East, there exist obvious disparities and differences affecting the kinds and types of risks involved. Therefore, these risks should be treated piecemeal when performing an overall assessment of crude oil import risks in China. It should also be noted that with respect to the Middle East there is still room for China to optimize the mix of source countries in order to reduce risks. China should raise the volume of imports coming from low risk countries as well as add new low risk exporting countries to its importing portfolio.

14/00724 Refinery scheduling of crude oil unloading with tank inventory management

Hamisu, A. A. *et al. Computers & Chemical Engineering*, 2013, 55, 134–147.

The aim of this study is to develop a methodology for short-term crude oil unloading, tank inventory management, and crude distillation unit (CDU) charging schedule using mixed integer linear programming (MILP) optimization model as an extension to an earlier study. The authors attempt to improve the previous model by adding an interval–interval variation constraint to avoid CDU charging rate fluctuation, a shutdown penalty within the scheduling cycle and a set up penalty for tank-tank transfer and introducing demand violation permit for a more flexible model against obtaining infeasible solution. Three different cases from the original paper were used to test the validity of the improved model. Comparison between cases 1 and 2 shows the advantage of using smaller time interval as the operating cost of case 2 is lower. Two scenarios were created from case 3 to show the benefits of the improved model in deciding the best schedule to use. The improved model was implemented using the CPLEX solver in GAMS.

14/00725 The energy efficiency of oil sands extraction: energy return ratios from 1970 to 2010

Brandt, A. R. *et al. Energy*, 2013, 55, 693–702.

It has been argued that the oil sands industry is not energy efficient: comparatively large energy inputs are required per unit of energy output from oil sands operations. Unfortunately, quantitative work to date in this area has suffered from poor data availability and uncertain methods. The authors apply a new methodology and new dataset to compute energy return ratios for the oil sands industry. They collected monthly oil sands energy consumption and output data from 1970 to 2010. Current oil sands operations have mine mouth net energy returns (NERs) of about 6 GJ output per GJ of energy consumed and point of use energy returns of about 3 GJ/GJ. Long-term trends show oil sands operations becoming significantly more efficient: point of use NER increased from about 1 GJ/GJ in 1970 to 3 GJ/GJ in 2010. These energy returns are lower than those observed in historical conventional oil operations, but low energy returns are not likely to hinder development of oil sands operations due to the large resource in place and the ability for largely self-fuelled pathways to return significant amounts of energy to society for every unit of external energy supplied.

Derived liquid fuels

14/00726 A comparative simulation of a novel gas to liquid (GTL) conversion loop as an alternative to a certain refinery gas flare

Ghorbani, A. *et al. Journal of Natural Gas Science and Engineering*, 2013, 11, 23–38.

Recently global attempt are focused on replacing gas flaring by environmentally friendly technologies, such as gas-to-liquid (GTL) technology. The main aim of this practice is preventing waste of energy and decreasing the emission of CO_2 and other harmful by-product gases. In order to fulfill this goal, improvement of GTL process efficiency seems necessary. For this purpose, in this work the performance of two different configurations is compared in basis of hydrogen component. In both, refinery purge gases are used as a feedstock where enter to reaction side of a hydrogen perm-selective membrane reformer. In the first configuration, steam reformer reactor is located outside the Fischer–Tropsch (F–T) synthesis loop while in the second one is placed inside the loop. A portion of generated hydrogen in the reformer is permeated through the membrane as a byproduct and the remaining is utilized in F–T synthesis reactions. The simulation results of the aforementioned loops show that the second configuration is better than the first one of operation. The results of second configuration show 87% hydrogen utilization in F–T reactions and 11% hydrogen production in steam reformer reactions and also 2% hydrogen exit by off gas in separator. Further advantages of this alternative are namely, lessening in CO_2 emission rate with a value of 0.8 for the first configuration ones and less than 0.33 to that of flaring, and more than 8430 barrels per day of heavy fraction hydrocarbons containing gasoline and butane fraction for a specified value (about 356.5 MMscfd) of purge gases.

14/00727 Atomization of petroleum-coke sludge slurry using effervescent atomizer

Ma, X. *et al. Experimental Thermal and Fluid Science*, 2013, 46, 131–138.

Experimental investigations were carried out on a bench-scale atomization test facility to explore the atomization performance of petroleum coke sludge slurry (PCSS) which comprises pulverized petroleum coke, sewage sludge, water and a certain amount of chemical additives. In the experiments, effervescent atomizer was employed to spray the petroleum coke sludge slurry. And effects of air injection pressure, air-to-liquid mass flow rate ratio (ALR), exit orifice diameter and rheological properties of petroleum coke sludge slurry with different amount of sewage sludge on the Sauter mean diameter (SMD or D_{32}) of the atomized droplets were investigated. Results suggest that petroleum coke particles have strong hydrophobic surface. Solid–liquid separation occurs between petroleum coke particles and water film during atomization. Sewage sludge is viscoelastic non-Newtonian fluids, which would influence the solid–liquid separation process when pulverized petroleum coke and sewage sludge are blended to prepare petroleum coke sludge slurry for atomization. SMD of atomized petroleum coke sludge slurry droplets decreases with ALR increase. However, SMD increases with spray axial distance downstream from the nozzle tip primarily and then decreases. Reduction of exit orifice diameter and increase of air injection pressure could improve the atomization performance, while sewage sludge would weaken the influence on variation of the atomized droplets diameters with increase of the spray axial distance and ALR.

14/00728 Co-liquefaction of rice straw and coal using different catalysts

Shui, H. *et al. Fuel*, 2013, 109, 9–13.

Co-liquefactions of a Chinese Shenfu sub-bituminous coal (SFSBC) and rice straw (RS) over four different coal liquefaction catalysts were carried out and the co-liquefied product preasphaltene (PA) was characterized by elemental analysis, FTIR and gel permeation chromatograms (GPC) measurements. It was found that the four catalysts gave different catalytic activities in the liquefaction of SFSBC and RS alone. Co–Mo/Al_2O_3 and SO_4^{2-}/ZrO_2 promoted the oil formation for RS liquefaction due to their solid acidic property, but FeS + S gave the highest catalytic activity for the liquefaction of SFSBC among the four catalysts used in this study. There existed a positive synergistic effect in the co-liquefaction of SFSBC and RS, and the main synergistic interaction was reflected by the promoted formation of oil and PA. The catalytic activities of the four catalysts in the co-liquefaction were quite different from their catalytic activities in the individual liquefaction of SFSBC and RS. FeS gave the lowest catalytic activity for the coal liquefaction alone among the four catalysts, but had the highest promotion to the synergistic effect in the total yield of liquefaction products in the co-liquefaction of SFSBC and RS. SO_4^{2-}/ZrO_2 diminished this synergistic effect for the co-liquefaction of SFSBC and RS due to its solid acidic property. It was found that the four catalysts used have higher catalytic activity for the PA, which is from coal liquefaction and converting this part of PA into AS and oil fraction. The average molecular weights of PAs from SO_4^{2-}/ZrO_2 and Co–Mo/Al_2O_3 catalysts were lower than those of PAs from FeS and FeS + S catalysts, suggesting that the catalytic hydrogenation activities of SO_4^{2-}/ZrO_2 and Co–Mo/Al_2O_3 are higher than those of FeS and FeS + S catalysts.

14/00729 Control of reflux and reboil flow rates for milli and micro distillation

Sundberg, A. T. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 753–760.

An accurate control of reflux and reboil flow rates for small scale distillation unit has been evaluated. Its feasibility was studied with a distillation column with good results. The distillation column was planar in shape, and it was operated in a horizontal orientation. Porous, open-cell metal foam was used as the column packing. The distillation unit could be operated at extremely low mass fluxes. The operation of the distillation unit was extremely stable, which was achieved thanks to the rigorous control of the fluid flow rates, and heat losses. The heat loss model was regressed based on distillation experiments with total reflux, and the model was used to optimize the temperature of the column shell in order to minimize the heat losses from the column. The volume of the reboiler, the preheaters, and the heat exchangers was minimized with the use of flat channels for intensified heat exchange. The total liquid hold-up of the system was less than 40 cm^3. The efficiency of the distillation unit was characterized for two binary and one ternary system.

14/00730 Hydrodynamic effect of oxygenated byproduct during Fischer–Tropsch synthesis in slurry bubble column

Yang, J. H. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 66, 27–35.

The Fischer–Tropsch reaction was performed using a pilot-scale slurry bubble column reactor (SBCR) and a lab-scale continuous stirred tank reactor (CSTR). In contrast to the CSTR, a transitory induction period was observed in the SBCR. This study investigated the catalyst performance during the induction period focusing on the hydrodynamic parameter changes inside the reactor. The authors measured the hydraulic pressure for the constant slurry thickness during FTS reaction. The FT wax product was regularly withdrawn using a metal filter and analysed for density, oxygen concentration, and compositional analysis. The liquid density was affected by the dilution of the initial liquid media by fresh FT product for the whole reaction time of 180 h. On the other hand, the oxygen concentration increased sharply for the initial 85 h and then reached the steady state. Accordingly, the gas hold-up and CO conversion were enhanced for the same period. The increase in the gas hold-up could be explained by the coalescence inhibition effect of oxygenated compounds, which were the main byproducts when iron-based catalysts were used. The dynamic gas disengagement technique was employed to identify the coalescence inhibition effect of alcohol in the hydrocarbon system using a cylindrical acrylic bubble column.

14/00731 Hydrothermal liquefaction (HTL) of microalgae for biofuel production: state of the art review and future prospects

Barreiro, D. L. *et al. Biomass and Bioenergy*, 2013, 53, 113–127.

Among the various types of biomass, microalgae have the potential of becoming a significant energy source for biofuel production in the coming years. Currently, research is mainly focusing on optimization of the cultivation methods and the conversion of just a single microalgae fraction (lipids for biodiesel production). Hydrothermal liquefaction is a method for thermochemical conversion of wet microalgae, producing a liquid energy carrier called 'bio-oil' or 'biocrude', next to gaseous, aqueous and solid by-products. A review of the available literature is presented here, analysing the influence of parameters such as temperature, holding time and catalyst dosage on the yield and properties of the different product fractions. Also, the strain selection and the status of the technology for hydrothermal processes are analysed. Finally, based on the findings obtained from the literature review, directions for future research are suggested.

14/00732 Optimal use of hybrid feedstock, switchgrass and shale gas for the simultaneous production of hydrogen and liquid fuels

Martín, M. and Grossmann, I. E. *Energy*, 2013, 55, 378–391.

This study presents a superstructure optimization approach for the integration of the simultaneous production of liquid fuels and hydrogen from switchgrass and shale gas. The process is based on Fischer–Tropsch (FT) technology in which the shale gas is reformed with steam, while the switchgrass is gasified and reformed (with steam or partial oxidation). The raw gas is cleaned up and its composition may be adjusted (using either water gas shift reaction or pressure swift adsorption). Next, the sour gases are removed before the liquid fuels are produced using an FT reactor. The heavy liquids are upgraded using hydrocracking to increase the yield towards FT-diesel. A sensitivity study on the raw material prices reveals that production costs for the biomass-shale gas facility are below $1/gal as long as biomass price is below $100/t and the price of the shale gas is not higher than $11.5/MMBTU. Furthermore, hydrogen is produced as long as the demand for liquid fuels can be met and there is enough shale gas available.

14/00733 Steam-CO_2 reforming of methane on Ni/γ-Al_2O_3-deposited metallic foam catalyst for GTL-FPSO process

Park, D. *et al. Fuel Processing Technology*, 2013, 112, 28–34.

The steam-CO_2 reforming (SCR) of methane on a Ni/γ-Al_2O_3-deposited metallic foam catalyst was assessed for the GTL-FPSO (gas to liquids-floating production, storage and offloading) process. The metallic foam catalyst was prepared by the wash-coating of a γ-Al_2O_3 layer and the subsequent impregnation of a Ni catalyst. The prepared Ni/γ-Al_2O_3/Ni foam catalyst was characterized by scanning electron microscopy and X-ray diffraction. The SCR reaction on the Ni/γ-Al_2O_3/Ni foam catalyst was evaluated at different temperatures and space velocities. A uniform and robust catalyst layer was formed on the surface of the Ni foam. The metallic foam catalyst showed a higher CH_4 conversion than a pellet catalyst. The durability of the metallic foam catalyst was evaluated at a space velocity of 130,000 h^{-1} for 50 h. The CH_4 conversion decreased by 10% compared to that after the reaction was initiated.

14/00734 Synthesis of LPG via DME from syngas in two-stage reaction system

Ma, X. *et al. Fuel Processing Technology*, 2013, 109, 1–6.

Synthesis of liquefied petroleum gas (LPG) via dimethyl ether (DME) from syngas was carried out in a two-stage reaction system, where syngas was transformed to DME in the first stage over the Cu–Zn–Al/ZSM-5 catalyst and then to hydrocarbons in the second stage over the Pd–Y catalyst. CO conversion and LPG selectivity were dominated by the first and second stage, respectively. CO conversion could be kept at a high level through the gradual increase of reaction temperature of the first stage, although there was a slight deactivation for the Cu–Zn–Al/ZSM-5 catalyst. LPG selectivity in hydrocarbons was more than 75% due to the proper pore size of Y zeolite and the presence of hydrogen. Coke deposition on Y zeolite was the reason for the decrease of LPG selectivity, but fortunately the selectivity of LPG could be recovered to a great extent by coke burning.

14/00735 The valorization of glycerol: economic assessment of an innovative process for the bioconversion of crude glycerol into ethanol and hydrogen

Varrone, C. *et al. Applied Energy*, 2013, 105, 349–357.

The worldwide energy demand has been continuously increasing, thus requesting more sustainable alternatives to the rapidly depleting fossil fuels. Therefore, biofuels such as hydrogen, bioethanol and biodiesel are gaining more importance as a renewable and pollution-free solution, which might give a significant contribution to the future energy mix. In recent years, the exponential growth of biodiesel production has led to a glycerol glut, however, according to some authors, crude glycerol might represent a suitable, abundant and low-priced feedstock for fermentation technologies. In this study, the authors performed an energetic and economic assessment of an innovative process, which is under development in the laboratory, for the bioconversion of crude glycerol into ethanol and hydrogen. Ongoing experiments showed the possibility to reach at least 26 g/L of ethanol, together with 9 L of hydrogen, in non-sterile conditions and without nutrient supplements. Since kinetics and ethanol concentration need to be further improved, the authors performed this study with a view to evaluate the possibility of reaching economic viability. Results showed that with 26 g/L of ethanol and a retention time as high as 120 h, the calculated energy cost would be about €0.019/kW h_{th} and €0.057/kW h_{el}, considering the contribution of both, hydrogen and bioethanol. Moreover, bioethanol cost would be as low as €0.21/L, even without taking into account the possible hydrogen revenues. These results are very promising and suggest that the process has reasonable chances to achieve economic viability, thus deserving further attention. The procedure followed in this work provided a realistic and concrete target to pursue in the future lab experiments, in order to bring this technology closer to the market.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

14/00736 A compact curved vibrating wire technique for measurement of hydrogen gas viscosity

Yusibani, E. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 1–5.

Studies with the view to application of a curved vibrating wire method to measure hydrogen gas viscosity have been done. A fine tungsten wire with a nominal diameter of 50 µm is bent into a semi-circular shape and arranged symmetrically in a magnetic field. The frequency domain response for forced oscillation of the wire is used for calculating the viscosity. Argon, nitrogen, helium and hydrogen viscosities have been measured at room temperature up to 0.7 MPa. The deviations with respect to existing equations suggest that with more refinements it may be possible to take gas viscosity measurements with a precision of less than 1%.

14/00737 Gas hydrate formation and accumulation potential in the Qiangtang Basin, northern Tibet, China

Fu, X. *et al. Energy Conversion and Management*, 2013, 73, 186–194.

The Qiangtang Basin is the biggest residual petroleum-bearing basin in the Qinghai–Tibet Plateau, and is also an area of continuous permafrost in south-west China with strong similarities to other known gas-hydrate-bearing regions. Permafrost thickness is typically 60–180 m; average surface temperature ranges from −0.2 to −4.0 °C, and the geothermal gradient is about 2.64 °C/100 m. In the basin, the Late Triassic Tumen Gela Formation is the most important gas source rock for gas, and there are 34.3×10^8 t of gas resources in the Tumen Gela Formation hydrocarbon system. Seventy-one potential anticline structural traps have been found nowadays covering an area of more than 30 km^2 for each individual one, five of them are connected with the gas source by faults. Recently, a large number of mud volcanoes were discovered in the central Qiangtang Basin, which could be indicative of the formation of potential gas hydrate. The North Qiangtang depression should be delineated as the main targets for the purpose of gas hydrate exploration.

14/00738 Microbial degradation of sedimentary organic matter associated with shale gas and coalbed methane in eastern Illinois Basin (Indiana), USA

Gao, L. *et al. International Journal of Coal Geology*, 2013, 107, 152–164.

Molecular biodegradation indices for extracts from five Pennsylvanian coals and six New Albany Shale (Devonian – Mississippian) samples from the eastern part of the Illinois Basin help constrain relationships between the degradation of biomarkers and the generation of coalbed methane and shale gas. Investigation of these gas source rocks of varying thermal maturity from different depths facilitates evaluation of the association of microbial degradation with biogenic gas formation distinct from thermogenic processes. Extensive biodegradation of both aliphatic and aromatic hydrocarbons is observed in the coal extracts, whereas in shale extracts only short-chain (C_{15}–C_{19}) *n*-alkanes from the shallowest depth appear to be microbially altered with minimal evidence for losses of acyclic isoprenoid alkanes and aromatic hydrocarbons. By contrast, biodegradation of aromatic hydrocarbons, specifically alkylated naphthalenes and phenanthrenes, occurs in coal extracts in concert with losses of *n*-alkanes attributable to microbial activity. Thus, the progress of hydrocarbon biodegradation in coals differs from the sequence recognized in petroleum where the effects of microbial alteration of aromatic constituents only appear after extensive losses of aliphatic compounds. The extent of hydrocarbon biodegradation in these coals also decreases with depth, as recorded by the $\Sigma(nC_{25}–nC_{30})$ index (i.e. abundance relative to $17\alpha(H),21\beta(H)$-hopane) among the aliphatic constituents and several aromatic compounds (methyl-, dimethyl-, and trimethylnaphthalenes, phenanthrene, and trimethyl- and tetramethylphananthrenes). However, the depth variations in the distributions of aliphatic and aromatic hydrocarbons in the shale extracts primarily reflect the effects of thermal maturity rather than biodegradation. Overall, variations in the extent and patterns of biomarker biodegradation among coals and shales likely reflect their distinct microbial consortia that can be attributed to differences in (i) surviving microorganisms and inoculations from meteoric water, (ii) the characteristics of the sedimentary organic matter, especially the preponderance of aromatic constituents in coals, and (iii) the accessibility to that substrate through pores and cleats. These results help constrain the processes involved in biodegradation and controls on its extent, which, in turn, assist in recognizing sites favourable for methanogenesis and improved estimates of biogenic gas resources in the Illinois Basin.

14/00739 Modeling of sulfur plugging in a sour gas reservoir

Hu, J. *et al. Journal of Natural Gas Science and Engineering*, 2013, 11, 18–22.

In order to scientifically and accurately predict the damage of sulfur deposition in a sour gas reservoir. Glomeration mechanism of precipitated sulfur in pores was analysed, based on conventional black-oil reservoir simulator, given the effect of sulfur deposition and irreducible water, a reservoir damage model is established in the presence of non-Darcy flow, the model can be used to describe the change of pressure with deposited sulfur. The results show that when reservoir pressure is lower than critical pressure, higher saturation degree of irreducible water may lead to pressure drop more quickly and velocity of sulfur precipitation becomes faster, gas limited production time becomes shorter when non-Darcy flow is considered.

Transport, storage

14/00740 A one-dimensional mathematical model of multi-component fluid flow in pipes and its application to rapid decompression in dry natural gas mixtures

Burlutskiy, E. *International Journal of Pressure Vessels and Piping*, 2013, 104, 30–36.

The paper presents a one-dimensional transient mathematical model of compressible thermal multi-component gas mixture flow in a shock tube. The set of mass, momentum and enthalpy conservation equations is solved for the gas phase. Thermo-physical properties of multi-component natural gas mixture are calculated by solving the equation of state (EOS) in the form of the Soave–Redlich–Kwong (SRK-EOS) model. The proposed mathematical model is validated against the experiments where the decompression wave speed in dry natural gases was measured at low temperatures and shows a good agreement with the experimental data at high and low initial pressure. The effect of the initial temperature on rapid decompression process is investigated numerically using the proposed model. Numerical results show that the proposed model simulates the decompression in natural gases much better and accurate than other models, and shows a great potential because it can be extended on the case of gas–liquid two-phase flow in a shock tube.

14/00741 CO_2 sequestration potential of Charqueadas coal field in Brazil

Santarosa, C. S. *et al. International Journal of Coal Geology*, 2013, 106, 25–34.

Although coal is not the primary source of energy in Brazil there is growing interest to evaluate the potential of coal from the south of the country for various activities. The I2B coal seam in the Charqueadas coal field has been considered a target for enhanced coal bed methane production and CO_2 sequestration. A detailed experimental study of the samples from this seam was conducted at the National Energy Technology Laboratory of Pittsburg, USA, with assistance from the Pontifícia Universidade Católica Do Rio Grande Do Sul, Brazil. Such properties as sorption capacity, internal structure of the samples, porosity and permeability were of primary interest in this characterization study. The samples used were low rank coals (high volatile bituminous and sub-bituminous) obtained from the I2B seam. It was observed that the temperature effect on adsorption capacity correlates negatively with as-received water and mineral content. Langmuir CO_2 adsorption capacity of the coal samples ranged from 0.61 to 2.09 mmol/g. The upper I2B seam appears to be overall more heterogeneous and less permeable than the lower I2B seam. The lower seam coal appears to have a large amount of micro-fractures that do not close even at 11 MPa of confining pressure.

14/00742 Development of a fast transient simulator for gas–liquid two-phase flow in pipes

Choi, J. *et al. Journal of Petroleum Science and Engineering*, 2013, 102, 27–35.

The objective of this study is to develop a simplified transient model and a simulator for gas–liquid two-phase flow in pipelines. The reliable predictions of liquid holdup and pressure drop are essential for pipeline design in oil and gas industry. In this study, the drift-flux approach is utilized to calculate liquid holdups. A modification of the power law correlation presented in an earlier study is suggested for pressure drop calculation. The proposed approach and correlation are continuous and flow pattern independent. Additionally, the developed model is simple and presents an easy tuning capability with either experimental data or synthetic data coming from steady-state simulators. The simplicity of the model allows quick implementation yielding in a faster simulator as compared to available commercial software. The developed simulator is tested with experimental data from an earlier study, which include two transient conditions; liquid flow rate changes and gas flow rate changes. The results of simulation are compared with OLGA (OiL and GAs simulator supplied by SPT group) simulations and show fair agreement in terms of liquid holdups and pressures.

14/00743 Economic nonlinear model predictive control for periodic optimal operation of gas pipeline networks

Gopalakrishnan, A. and Biegier, L. T. *et al. Computers & Chemical Engineering*, 2013, 52, 90–99.

This study considers a non-linear model predictive control (NMPC) formulation for optimizing the operational costs of gas pipeline networks. The major operating cost comes from running the compressors, which compensate for the frictional pressure loss as gas flows over long distances. The authors use an economic NMPC formulation, which directly considers the compressor operating cost as the controller objective. Due to diurnal gas demands, the optimal operation is a cyclic steady state. The controller objective and terminal constraints are suitably defined to ensure asymptotic convergence and closed-loop stability of the cyclic steady state. It is shown through simulations that the performance of the economic NMPC formulation is better than a tracking NMPC. The inherent robustness of the formulation also ensures convergence to a region around the cyclic steady state when demand forecasts are inaccurate. The large-scale NLP is also solved within a reasonable CPU time making it practical for online application.

14/00744 Experimental study of counter-current gas–droplet flow limitation in a 30 cm pipe

Miwa, S. *et al. Chemical Engineering Science*, 2013, 92, 167–179.

In the present study, gas–liquid two-phase flow at the counter-current flow limitation (CCFL) condition in a relatively large pipe is investigated analytically and experimentally. Droplet behaviour and stable counter-current flow criteria are analysed by studying the interaction between downward moving liquid droplets and upward gas flow. An analytical model based on the drift flux model was developed to predict the onset of CCFL phenomena. The model takes into account various factors that may be encountered in the industry including gas velocity profile, droplet fraction profile, and velocity fluctuation factor. Analyses show that maintaining a uniform gas velocity profile and a stable gas flow rate is the key to prevent droplet carry-over and hence delaying the CCFL condition. For droplet–gas interaction, droplet size in the distorted particle regime is the major contribution. An experimental facility consisting of a 30 cm test section pipe was designed and constructed to perform a fundamental study of counter-current droplet–gas flow. A dataset for the onset of CCFL at varying operating conditions was established. The proposed model showed the ability to predict the onset of CCFL in the counter-current two-phase flow.

14/00745 Gas cleaning challenges for coal-fired oxy-fuel technology with carbon capture and storage

Wall, T. *et al. Fuel*, 2013, 108, 85–90.

As one of the three major carbon capture technologies associated with carbon capture and storage (CCS), oxy-fuel technology is currently undergoing rapid development with a number of international demonstration projects commencing in the progression towards commercialization. The CO_2 gas quality from oxy-fuel differs from pre- and post-combustion technologies, having higher levels of inert gases, oxygen, sulfur and nitrogen gases and other impurities such as mercury in the flue gas. Operations are available for adjusting gas quality, in the furnace, and by cleaning and treating flue gas with further removal of impurities during compression. Thus, knowledge of the impact of gas quality on power plant and materials, on transport systems and also gas quality regulations for storage is required, as the cost of gas cleaning is likely to be more significant for oxy-fuel than for other carbon capture technologies. The gas cleaning challenges are identified, with examples of two issues, one being the impact of sulfur impurities, and the other being gas quality impacts and control influencing CO_2 compression.

14/00746 Innovative process for biogas upgrading with CO_2 storage: results from pilot plant operation

Baciocchi, R. *et al. Biomass and Bioenergy*, 2013, 53, 128–137.

An innovative biogas upgrading method that, differs from the currently employed commercial techniques, allows also to capture and store the separated CO_2 is investigated. This process, named alkali absorption with regeneration (AwR), consists in a first step in which CO_2 is separated from the biogas by chemical absorption with an alkali aqueous solution followed by a second step in which the spent absorption solution is regenerated for reuse in the first step of the upgrading process and the captured CO_2 is stored in a solid and thermodynamically stable form. The latter process is carried out contacting the spent absorption solution, rich in carbonate and bicarbonate ions, with a waste material – air pollution control residues from waste-to-energy plants – characterized by a high content of calcium hydroxide and leads to the precipitation of calcium carbonate and to the regeneration of the alkali hydroxide content of the solution. The process was tested in a specifically designed pilot plant fed with $20\,m^3\,h^{-1}$ (gas at standard conditions of 273 K and 1001 kPa) of landfill gas. Results showed that a high CH_4 content in the outlet gas can be obtained using a $3.8\,mol\,L^{-1}$ NaOH aqueous solution with a solution/landfill gas ratio of about $9\,L\,m^{-3}$ (gas at standard conditions of 273 K and 1001 kPa). The regeneration process proved to be feasible, but its efficiency was limited by several factors to maximum values in the range of 50–60 %, showing to decrease with higher NaOH concentrations in the absorption solution. Absorption tests with regenerated load solutions after appropriate NaOH makeup, did not show appreciable differences with respect to raw solutions.

14/00747 Recent progresses in experimental investigation and finite element analysis of ratcheting in pressurized piping

Chen, X. *et al. International Journal of Pressure Vessels and Piping*, 2013, 101, 113–142.

This article presents an overview of recent progresses in experimental investigation and finite element analysis (FEA) of ratcheting behaviour of pressurized piping. Ratcheting, namely the cyclic accumulation of plastic deformation, occurs when the structures are subjected to a primary load with a secondary cyclic load if the applied loads are high enough to make the structures yield. Typical piping structures including straight pipes, elbow pipes and piping joints have been investigated experimentally under mechanical or thermal cyclic loading. Finite element analyses with several well-developed constitutive models implemented in the commercial software ANSYS and ABAQUS have been conducted to simulate and predict the ratcheting behaviour of pressurized piping. Based on such experimental and FEA research, ratcheting boundaries have been determined with the final aim of aiding the safety design and assessment of engineering piping structures. Some suggestions for structure ratcheting study are proposed.

14/00748 Scheduling a multi-product pipeline network

de Souza Filho, E. M. *et al. Computers & Chemical Engineering*, 2013, 53, 55–69.

Every day, several millions of oil barrels are moved around the world in imports and exports and domestically within countries. While ships are the main mode for intercontinental transport, pipelines are the chief form of transcontinental transport, while regional and local transport is performed by trains and trucks. Despite high installation costs, pipelines are considered highly efficient as a mode for transporting large amounts of oil and oil products over long distances, because they offer lower operation costs, higher reliability rates, lower product loss rates, less environmental impact, and less susceptibility to adverse weather conditions than other modes. This study deals with a multi-product pipeline system that transports a set of oil products (diesel, gasoline and kerosene, for example), which have to be moved from points (operating areas) where they are produced or stored (refineries, terminals) to points where they are needed (other refineries, distribution centres, terminals, ports, customers) through a pipeline or set of pipelines. The present study contributes primarily by offering an efficient tool for the problem of scheduling multi-product pipeline networks. The methodology proposed takes the approach of discretizing both pipelines and planning horizon and combines an efficient mixed integer linear programming model with a post-processing heuristic. When compared with previous models, the authors propose a more efficient one in which the set of volumetric constraints is modelled in the form of knapsack cascading constraints and constraints on products in pipeline sections, which made for significantly improved performance in the experiments that were conducted. The proposed methodology thus constitutes an advance in terms of modelling the problem, making it feasible to solve problems increasingly close to the realities confronting oil industry operators.

14/00749 Synergistic kinetic inhibition of natural gas hydrate formation

Daraboina, N. *et al. Fuel*, 2013, 108, 749–757.

Rocking cells were used to investigate the natural gas hydrate formation and decomposition in the presence of kinetic inhibitor, Luvicap. In addition, the influence of polyethylene oxide (PEO) and NaCl on the performance of Luvicap was investigated using temperature ramping and isothermal experiments. Luvicap decreased the hydrate nucleation temperature in ramping and increased the hydrate nucleation time at fixed temperatures. The presence of PEO and NaCl enhanced the nucleation inhibition strength of Luvicap. However the addition of Luvicap promoted the hydrate growth after nucleation. PEO does not affect hydrate growth whereas NaCl reduced the hydrate growth both in the presence and absence of Luvicap. In addition complex two-stage hydrate growth was observed in the presence of Luvicap. Moreover, the hydrate formed in the presence of inhibitor took longer time/higher temperature to decompose completely. One should consider this complex inhibitor-mediated hydrate formation and decomposition kinetics when screening and designing kinetic inhibitors for field applications.

14/00750 The research and motor octane numbers of liquefied petroleum gas (LPG)

Morganti, K. J. *et al. Fuel*, 2013, 108, 797–811.

This paper presents an experimental study of the research (RON) and motor (MON) octane numbers of liquefied petroleum gas (LPG). A comprehensive set of RON and MON data for mixtures of propane, propylene (propene), n-butane and iso-butane are presented, using a method that is consistent with the currently active ASTM research and motor test methods for liquid fuels. Empirical models which relate LPG composition to its RON and MON are then developed, such that the simplest relationships between the constituent species' mole fractions and the mixture octane rating are achieved. This is used to determine the degree of non-linearity between the composition and the RON and MON of different LPG mixtures. Finally, implications for LPG fuel quality standards are discussed briefly, as part of a suggested, more substantial undertaking by the community which also revisits the standard test procedures for measuring the RON and MON of LPG.

14/00751 Unsteady double diffusive natural convection in porous media – application to CO_2 storage in deep saline aquifer reservoirs

Bouzgarrou, S. *et al. Energy Procedia*, 2013, 36, 756–765.

Storage capacity of carbon dioxide (CO_2) in deep saline aquifers is a challenging task. Therefore, an assessment must be performed to determine whether there is sufficient capacity in a storage site for any CO_2 sequestration project. This study evaluated the CO_2 storage capacity for a simplified reservoir system, which the layered potential storage formations are overlaid by sealing cap rock. In this paper, the authors investigate numerically the storage of CO_2 at supercritical conditions in deep saline aquifer reservoirs. Numerical simulations were carried out on non-deformable saturated porous material inside a vertical enclosure, assumed to be impermeable and isolated on three sides. The porous medium is considered to be homogeneous and isotropic with constant thermo-physical properties with the exception of the density of the fluid varying according to Boussinesq approximations. A dynamic model assuming that flow is two-dimensional and obeying to Darcy's law for motion has been used. It is assumed that the thermal equilibrium assumption is valid. The set of the conservation equations along with the appropriate initial and boundary conditions have been resolved numerically by the classical finite volume method. Spatio-temporal variations of different state variables such as pressure, velocity, temperature and concentration were numerically simulated and plotted versus different controlling parameters particularly, thermal and solutal Rayleigh numbers and Lewis number. Great attention was paid to examine the sensitivity of heat and mass transfer rates according to the reservoir form and the operating conditions. The main results indicate that when the Rayleigh number increases, natural convection intensifies. The effect of temperature is very clear and it intensifies the mass diffusion in the field. It can be concluded that the diffusion in the transverse direction becomes more intense as the medium gets higher. Furthermore, fingering behaviour is more pronounced with the thermal effect than that without this parameter. Heat and mass transfer aspects of CO_2 sequestration simulation results show that the non-linear behaviour of the flow is strongly dependent on the solutal and thermal Rayleigh number as well as on the Lewis number.

14/00752 Upgrading of associated petroleum gas into methane-rich gas for power plant feeding applications. Technological and economic benefits

Zyryanova, M. M. *et al. Fuel*, 2013, 108, 282–291.

Laboratory studies of the reaction of steam reforming of light hydrocarbons into methane–hydrogen mixture were performed. Ni- and Ru-containing systems were studied as the catalysts. The design, scale-out, and operation of an associated petroleum gas (APG) catalytic reformer integrated with evaporator-heat-exchanger, water condenser and flame burner were reported. Conversion of heavier hydrocarbon components into methane–hydrogen gas mixture exceeded 95–99% during testing the catalytic reformer at 270–360 °C. Increasing reaction temperature led to increasing H_2 and CO contents in the reaction mixture and complete conversion of liquefied petroleum gas and ethane fractions. Both initial and reformed APG were used for fuelling a power generation unit on the base of gas internal combustion engine MTES-30. In case of initial APG fuelling, the power derating was 22%, exhaust gas contained black smoke. When the power generation unit was fuelled by methane–hydrogen mixture produced by APG catalytic reforming, the engine power attained the nominal value; the engine showed excellent dynamic and temperature characteristics, stably supported crank rotation frequency. According to economic analysis concerning different types of power plants with electric power of ~1000 kW, the plants equipped with a catalytic reformer of APG into methane–hydrogen mixture show faster payback of capital investments, as compared to the plants fed by APG directly, due to longer service life, longer overhaul intervals, and low rated power losses. Catalytic reforming of APG into methane–hydrogen mixture is a promising approach for solving APG utilization problem.

14/00753 Using mixed tertiary amines for gas sweetening energy requirement reduction

Fouad, W. A. and Berrouk, A. S. *Journal of Natural Gas Science and Engineering*, 2013, 11, 12–17.

Studies have demonstrated the positive impact of mixing primary/tertiary or secondary/tertiary amines on the efficiency of amines sweetening processes in terms of gas purification and/or the process energy requirements. This paper discusses the use of amine solvents that consist of two tertiary amines namely methyl-diethanolamine (MDEA) and tri-ethanolamine (TEA). A kinetic approach was used to explain results obtained from process simulation of Habshan gas sweetening unit in Abu Dhabi, UAE. Results show that up to 3.0% reduction in the unit running cost can be obtained using the mixture (40% wt MDEA + 5% wt TEA) while meeting the sweet gas specifications in terms of H_2S and CO_2 concentrations. The lean amine loading was fixed at a value of 0.005. Results for the (40% wt MDEA + 5% wt TEA) mixture were compared to the results of the standardized (45% wt MDEA) solvent used in Habshan and other possible primary/tertiary and secondary/tertiary amine mixtures. This reduction in cost was achieved through a decrease in the plant raw materials cost and in both regenerator reboiler and trim cooler energy requirements.

Economics, business, marketing, policy

14/00754 A numerical method to predict flame fractal dimension during gas explosion

Wada, Y. and Kuwana, K. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 392–395.

Accurate prediction of the flame propagation velocity during a gas explosion is essential to assess its consequences and to evaluate the risk level. The propagating premixed flame is self-turbulized due to the hydrodynamic instability, resulting in a fractal flame structure. It is therefore important for accurate prediction of flame speed to understand the flame's fractal structure in detail and to predict its fractal dimension in particular. Numerical simulations of spherically-propagating flames have been previously attempted for such purposes. There are, however, difficulties to accurately predict the fractal dimension from the result of the numerical simulation of a spherically-propagating flame. This study proposes a method to easily predict the fractal dimension based on the numerical simulation of a planar flame. Planar flame propagation is simulated for different sizes of computational domain. The fractal dimension can be determined from the dependence of flame speed on computational domain size. The determined fractal dimension is favourably compared with previous experimental results.

14/00755 China's natural gas: resources, production and its impacts

Wang, J. *et al. Energy Policy*, 2013, 55, 690–698.

In order to achieve energy consumption targets, and subsequently reduce carbon emissions, China is working on energy strategies and policies aimed at actively increasing the consumption of natural gas – the lowest carbon energy of the fossil fuels, and to enhance the proportion of gas in total primary energy consumption. To do this, it is a necessary prerequisite that China must have access to adequate gas resources and production to meet demand. This paper shows that the availability of domestic gas resources are overestimated by China's authorities due to differences in classification and definitions of gas resources/reserves between China and those accepted internationally. Based on official gas resource figures, China's gas production remains low with respect to the projected demand, and will only be 164.6 bcm in 2020, far lower than the 375 bcm of forecast demand. The gap between gas production and demand will reach 210.4 bcm by 2020. Existing plans for the importation of gas and the development of unconventional gas will not close this gap in the next 10 years, and this situation will therefore present a severe challenge to China's gas security, achievement of targets in improving energy consumption structure and reducing carbon emissions.

14/00756 Computer-aided process engineering in oil and gas production

Nikolaou, M. *Computers & Chemical Engineering*, 2013, 51, 96–101.

As oil and gas production moves to ever more challenging areas, increased use of technology becomes increasingly important. One technology that can contribute towards achieving safe and economic production from such areas is computer-aided process engineering. The use of such technology is outlined for two (of many) instances: managed pressure drilling (MPD) for deep-offshore applications and natural gas production from shales. A broader picture of the importance of computer-aided process engineering for energy is briefly touched on.

14/00757 Economic appraisal of shale gas plays in continental Europe

Weijermars, R. *Applied Energy*, 2013, 106, 100–115.

This study evaluates the economic feasibility of five emergent shale gas plays in continental Europe. Each play is assessed using a uniform field development plan with 100 wells drilled at a rate of 10 wells/year in the first decade. The gas production from the realized wells is monitored over a 25 year life cycle. Discounted cash flow models are used to establish for each shale field the estimated ultimate recovery (EUR) that must be realized, using current technology cost, to achieve a profit. The analyses of internal rates of return (IRR) and net present values indicate that the Polish and Austrian shale plays are the more robust, and appear profitable when the strict P90 assessment criterion is applied. In contrast, the Posidonia (Germany), Alum (Sweden) and a Turkish shale play assessed all have negative discounted cumulative cash flows for P90 wells, which puts these plays below the hurdle rate. The IRR for P90 wells is about 5% for all three plays, which suggests that a 10% improvement of the IRR by sweet spot targeting may lift these shale plays above the hurdle rate. Well productivity estimates will become better constrained over time as geological uncertainty is reduced and as technology improves during the progressive development of the shale gas fields.

14/00758 Economic competitiveness of off-peak hydrogen production today – a European comparison

Mansilla, C. *et al. Energy*, 2013, 55, 996–1001.

Hydrogen has a wide range of applications. In view of the environmental benefits, hydrogen can be produced by decarbonized means. When alkaline electrolysis is the selected process, extra value is offered by flexible operation that could bring both; an opportunity to reduce the cost of hydrogen produced (by consuming electricity during off-peak hours, and stopping the process during peak hours) and also a complementary tool to help balancing of the electric system. This paper assesses the profitability of market-driven operation for three different markets: France, Germany and Spain, with an analysis on the spot market. The market that exhibits the biggest potential in terms of profitability thanks to flexible operation is the French one, for each studied year. France is also the country that has the smallest installed renewable capacity amongst three considered countries. The gain on the hydrogen production cost allowed by the optimization is less than 3%. Hence, market-driven operation does not seem highly favourable to valorize fluctuating hydrogen production, when only the market price opportunities are considered. The balancing tool provided by the electrolysis system needs to be specifically valorized, in order to make flexible operation profitable.

14/00759 Energy institutional and organisational changes in EU and Russia: revisiting gas relations

Boussena, S. and Locatelli, C. *Energy Policy*, 2013, 55, 180–189.

This paper tries to shed light on why gas relations between the European Union (EU) and Russia, which were previously stable, have deteriorated since the introduction of institutional changes in the two regions. After identifying the areas of divergence in the context of European gas market liberalization, the authors then attempt to examine them in the context of the differing approaches to structuring this sector. The model of vertically unbundled network industries promoted by the EU is no longer the one that Russia intends to implement in its gas sector, despite the big changes taking place in its domestic market. All this is happening in a context where the economic stakes are very high. For the EU and its gas companies, access to Russia's hydrocarbon resources is a key question. For Gazprom, the question is whether or not it can define strategies that are flexible enough to adapt to the changing conditions in the European gas market.

14/00760 Investments in combined cycle natural gas-fired systems: a real options analysis

Zambujal-Oliveira, J. *et al. International Journal of Electric Power & Energy Systems*, 2013, 49, 1–7.

Energy projects with extended life cycle and initial investments can be non-profitable under discount cash flow methods. Therefore, real options analysis has become relevant as a pricing technique for these types of projects, with private risks and high investment levels. Following this question, this study analyses different real options approaches to select the most adequate for making investment decisions in the energy sector. Combined cycle natural gas-fired plants constitute relevant generation assets that building decisions can mostly be studied by real options tools. Because traditional pricing approaches (e.g. net present value, internal rate of return, benefit-cost ratio) fail to take into account the worth of flexibility, conditions for creating significantly large options-based value can be found. Being unable to capture the value associated with the decision maker's ability to dynamically react to changing market conditions, these assets constitute a fine example of asset flexibility which contributes to increasing its intrinsic value. Employing a real options approach that fails to capture the uncertainty of all the periods and proposes a process that determines directly the uncertainty associated with the first period, the paper concludes that its use can be considered fair. However, it shows that long periods of operation and poor adhesion to the geometric Brownian motion by the project returns might call into question its use in the energy market. The values for option pricing have remained inside acceptable ranges but some shortfalls could be found. First, the study employs Monte Carlo simulations which can be viewed as forward-looking processes and option pricing problems need backward recursive solutions. Second, the study demonstrates that its simplicity reaches results as accurate as those derived from approaches with additional complexity and computational requirements.

14/00761 Market-driven operational optimization of industrial gas supply chains

Manenti, F. and Rovaglio, M. *Computers & Chemical Engineering*, 2013, 56, 128–141.

This paper deals with the operational optimization of industrial gas supply chains. Industrial gas networks differ from other applications and require a rather special and shrewd approach to modelling and optimization issues. Currently in industrial gas plants: (i) the raw material is free; (ii) binding contracts and clauses place tight limits on supplies, production and distribution; (iii) electric energy cost fluctuations wield a greater influence over overall production than in other industrial areas; (iv) market demand is subject to multifaceted fluctuations and uncertainties; (v) long-term market demand is usually regulated by take-or-pay contracts; (vi) main users are on-site or connected via pipeline; and (vii) cryogenic storage constitutes a significant expense and encourages companies to veer toward just-in-time production. This paper also provides very general guidelines for dealing with the aforementioned peculiarities, and compares plant-wide and enterprise-wide optimizations of industrial gas networks. An existing network is adopted as industrial case study.

14/00762 Natural gas consumption and economic growth in Pakistan

Shahbaz, M. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 87–94.

Natural gas is a dominant fuel in Pakistan. It offers the cheapest and a cleaner alternative source of energy. This paper examines the relationship of natural gas consumption and economic growth in Pakistan. It includes capital, labour and exports in the model with multivariate framework. The ARDL bounds testing approach to cointegration and innovative accounting approach are employed to investigate the dynamic causality relationships among the variables. The authors found the long-run relationship among the variables. Natural gas consumption, capital, labour and exports are positively affecting economic growth in Pakistan. Furthermore, the authors support the natural gas consumption-led-growth hypothesis and suggest that natural gas conservation policies may retard economic growth.

14/00763 Natural gas scenarios in the U.S. power sector

Logan, J. *et al. Energy Economics*, 2013, 40, 183–195.

The US power sector is being transformed by the recent rise in the availability and use of unconventional natural gas, specifically shale gas. That transformation has already produced some of the most significant changes in the operation of the portfolio of electricity generation since 1945. Further implications are likely. To that end, the authors present results from numerical modelling of different US power sector futures. These futures assess questions affecting today's natural gas and electric power markets, including the impacts of: forthcoming Environmental Protection Agency rules on power plants, decarbonization options such as a clean energy standard (CES), potential improvements in key generation technologies, expanded use of natural gas outside of the power generation sector, and higher costs for natural gas production – assumed to arise from more robust environmental and safety practices in the field. The simulations were done using the ReEDS model looking out to the year 2050. ReEDS is a capacity expansion model that determines the least-cost combination of generation options that fulfill a variety of user-defined constraints such as projected load, capacity reserve margins, emissions limitations, and operating lifetimes. The baseline scenario shows strong growth in natural gas generation, leading to a roughly 2.5-fold increase in gas demand by 2050. Many other scenarios also see strong growth in gas-fired generation, highlighting questions about portfolio diversity, climate change, and research and development prioritization.

14/00764 Parallel nonconvex generalized Benders decomposition for natural gas production network planning under uncertainty

Li, X. *Computers & Chemical Engineering*, 2013, 55, 97–108.

A scenario-based two-stage stochastic programming model for gas production network planning under uncertainty is usually a large-scale non-convex mixed-integer non-linear programme (MINLP), which can be efficiently solved to global optimality with non-convex generalized Benders decomposition (NGBD). This paper is concerned with the parallelization of NGBD to exploit multiple available computing resources. Three parallelization strategies are proposed, namely, naive scenario parallelization, adaptive scenario parallelization, and adaptive scenario and bounding parallelization. Case study of two industrial natural gas production network planning problems shows that, while the NGBD without parallelization is already faster than a state-of-the-art global optimization solver by an order of magnitude, the parallelization can improve the efficiency by several times on computers with multicore processors. The adaptive scenario and bounding parallelization achieves the best overall performance among the three proposed parallelization strategies.

14/00765 What causes price volatility and regime shifts in the natural gas market

Lin, B. and Wesseh Jr., P. K. *Energy*, 2013, 55, 553–563.

Gas sector volatility is of interest because it affects decisions made by producers and consumers and also influences investors' decision in gas-related investments, portfolio allocation and risk management. This paper therefore attempts to explain the behaviour of natural gas index returns and in so doing proposes application of a pure Markov-switching volatility model whose variance is subject to shift in regime. The authors show that regime-switching is clearly present in the natural gas market and such should not be ignored. All ARCH effects that show up in weekly natural gas index returns data die out almost completely after allowing for Markov-switching variance. Volatility regimes identified by the model correlate well with major events affecting supply and demand for natural gas. Out-of-sample tests indicate that the regime switching model performs noticeably better than a wide range of volatility models considered regardless of evaluation criteria, thus providing a better framework for the policy maker or financial historian interested in studying factors behind the evolution of volatility and to natural gas futures traders interested in short-term volatility forecasts. As risk-hedging decisions rely critically on assumptions about volatility, policies based on the transition probabilities are likely to be more conservative.

Derived gaseous fuels

14/00766 An experimental and detailed chemical kinetic modeling study of hydrogen and syngas mixture oxidation at elevated pressures

Kéromnès, A. *et al. Combustion and Flame*, 2013, 160, (6), 995–1011.

The oxidation of syngas mixtures was investigated experimentally and simulated with an updated chemical kinetic model. Ignition delay times for $H_2/CO/O_2/N_2/Ar$ mixtures have been measured using two rapid compression machines and shock tubes at pressures from 1 to 70 bar, over a temperature range of 914–2220 K and at equivalence ratios from 0.1 to 4.0. Results show a strong dependence of ignition times on temperature and pressure at the end of the compression; ignition delays decrease with increasing temperature, pressure, and equivalence ratio. The reactivity of the syngas mixtures was found to be governed by hydrogen chemistry for CO concentrations lower than 50% in the fuel mixture. For higher CO concentrations, an inhibiting effect of CO was observed. Flame speeds were measured in helium for syngas mixtures with a high CO content and at elevated pressures of 5 and 10 atm using the spherically expanding flame method. A detailed chemical kinetic mechanism for hydrogen and H_2/CO (syngas) mixtures has been updated, rate constants have been adjusted to reflect new experimental information obtained at high pressures and new rate constant values recently published in the literature. Experimental results for ignition delay times and flame speeds have been compared with predictions using a newly revised chemical kinetic mechanism, and good agreement was observed. In the mechanism validation, particular emphasis is placed on predicting experimental data at high pressures (up to 70 bar) and intermediate- to high-temperature conditions, particularly important for applications in internal combustion engines and gas turbines. The reaction sequence $H_2 + H\dot{O}_2 \leftrightarrow \dot{H} + H_2O_2$ followed by $H_2O_2\ (+M) \leftrightarrow \dot{O}H + \dot{O}H\ (+M)$ was found to play a key role in hydrogen ignition under high-pressure and intermediate-temperature conditions. The rate constant for $H_2 + H\dot{O}_2$ showed strong sensitivity to high-pressure ignition times and has considerable uncertainty, based on literature values. A rate constant for this reaction is recommended based on available literature values and on this mechanism validation.

14/00767 Autothermal reforming of synthetic JP-8 derived from a coal syngas stream

Scenna, R. *et al. Fuel*, 2013, 108, 731–739.

The performance characteristics of a coal based synthetic JP-8 fuel were evaluated on an autothermal reformer experimental test stand. The target application for the reformate was a solid oxide fuel cell power unit. The synthetic JP-8 fuel was derived through the Fischer–Tropsch process, resulting in a predominantly paraffin based fuel. The synthetic JP-8 fuel was reacted in an atmospheric pressure autothermal reformer with noble metal catalysts under conditions of steam-to-carbon ratio of 2.0, fuel equivalency energy flow of 3.33 kW thermal to 6.66 kW thermal, and variable oxygen-to-carbon ratios of 0.8–1.2. For all fuel equivalency flow rates investigated, fuel conversion of greater than 96% were achieved. The synthetic fuel produced high reforming efficiencies of up to 92.2%, with hydrogen concentrations up to 36.5%. The results show that coal-derived JP-8 fuels can produce high reforming efficiencies, with high hydrogen concentrations while minimizing carbon formation in an autothermal reformer reactor.

14/00768 Co-gasification of crude glycerol with lignocellulosic biomass for enhanced syngas production

Skoulou, V. K. and Zabaniotou, A. A. *Journal of Analytical and Applied Pyrolysis*, 2013, 99, 110–116.

The present work concerns the co-gasification of crude glycerol (CG), a by-product of biodiesel industry, with locally available lignocellulosic biomass aiming at the production of syngas and further promotion of power production in dedicated bioenergy units. Co-gasification of CG with olive kernel (OK), an agro-residue issued from the intensive olive oil production sector in south-east Europe, was performed in a laboratory fixed bed reactor at $T = 750–850\,^{\circ}C$ with $\lambda = 0.2–0.4$ and in the three different mixing levels of 24, 32 and 49 wt% of CG in OK. Co-gasification of CG with OK found to favour the gas yield which increased from 0.4 to $1.2\,N\,m^3/kg$ for the mixture of 49 wt% of CG in biomass. Additionally H_2 concentration increased from 19 to 33%(v/v) in the gasification gas while the tar yield decreased from 19.5 to 2.4 wt% at conditions of $T = 850\,^{\circ}C$ and $\lambda = 0.4$.

14/00769 Coal-based synthetic natural gas (SNG): a solution to China's energy security and CO_2 reduction?

Ding, Y. *et al. Energy Policy*, 2013, 55, 445–453.

Considering natural gas (NG) to be the most promising low-carbon option for the energy industry, large state owned companies in China have established numerous coal-based synthetic natural gas (SNG) projects. The objective of this paper is to use a system approach to evaluate coal-derived SNG in terms of life-cycle energy efficiency and CO_2 emissions. This project examined main applications of the SNG and developed a model that can be used for evaluating energy efficiency and CO_2 emissions of various fuel pathway systems. The model development started with the GREET model, and added the SNG module and an end-use equipment module. The database was constructed with Chinese data. The analyses show when the SNG are used for cooking, power generation, steam production for heating and industry, life-cycle energies are 20–108% higher than all competitive pathways, with a similar rate of increase in life-cycle CO_2 emissions. When a compressed natural gas car uses the SNG, life-cycle CO_2 emission will increase by 150–190% compared to the baseline gasoline car and by 140–210% compared to an electric car powered by electricity from coal-fired power plants. The life-cycle CO_2 emission of SNG-powered city bus will be 220–270% higher than that of traditional diesel city bus. The gap between SNG-powered buses and new hybrid diesel buses will be even larger – life-cycle CO_2 emission of the former being around four times of that of the latter. It is concluded that the SNG will not accomplish the tasks of both energy conservation and CO_2 reduction.

14/00770 Cogeneration of substitute natural gas and power from coal by moderate recycle of the chemical unconverted gas

Li, S. *et al. Energy*, 2013, 55, 658–667.

The thermodynamic analysis and the coupling and optimization between chemical synthesis and power generation in a polygeneration system are presented. Unlike full conversion of syngas into chemicals in the traditional synthetic natural gas (SNG) production system, by moderate conversion the sharp increase in energy consumption for SNG synthesis can be avoided in the new system. Also, by recovering the chemical unconverted gas for combined cycle, electricity is cogenerated efficiently. Results show that the overall efficiency of the novel system can be as high as 59%–65%. And compared to single production systems, the energy saving ratio (ESR) of the new system is over 11.0% and the energy consumption for SNG production can be decreased by around 12%. Sensitivity analysis shows that an optimized conversion ratio of SNG chemicals-to-power-output ratio, recycle ratio of the unconverted gas Ru, and pressure ratio of gas turbine can lead to the maximum of ESR. Abolishing the syngas composition adjustment and improving the inlet temperature of gas turbine both can help to enhance the system efficiency. Under low Ru, improving the H_2/CO mole ratio in the syngas helps to improve system efficiency, while under high Ru, an optimized H_2/CO can lead to the maximum of ESR.

14/00771 Control assessment for heat integrated systems. An industrial case study for ethanol recovery

Mauricio-Iglesias, M. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 60–70.

Heat integration is essential for reducing the energy consumption of process industries. However, it may render the dynamic operation more interactive and difficult to control. This paper assesses the implications of heat integration in controllability and performance in energy reduction. The assessment, both on open loop and closed loop, was carried out based on an industrial case study and compared to a modified case without heat integration. Although the heat integrated system displayed a certain deterioration of controllability, the control system made possible an efficient operation. To this goal, different control systems were tested, from a decentralized control system to a model predictive controller. The type of controller used in the process barely influenced the performance of the process since the aim was exclusively to ensure the regulation of the process to fixed setpoints. The reduction of energy consumption achieved thanks to heat integration was considerably larger than the losses due to poor control of the process, confirming the importance of heat integration in energy intensive processes.

14/00772 Design and performance evaluation of dry cleaning process for syngas

Sharma, S. D. *et al. Fuel*, 2013, 108, 42–53.

Coal gasification is one of the most promising options for clean, efficient and continuous power generation, though little progress has been made towards its commercialization. One of the main hurdles of the commercialization is reliability of the syngas cleaning process involving separation of critical impurities which can adversely affect the downstream process, and may result in plant shutdown. For example, failure of particulate capturing operation could have instant effect on downstream turbine, catalytic membrane, fuel cell and CO_2 separation, therefore hot filtration is considered as the most critical process step in the gas cleaning process. Failure of sulfur, chlorine, alkali and trace element capture steps may also cause serious damage to the downstream processes but the effect will be noticeable after a relatively longer period of operation. During this period it could be possible to take some corrective actions, either manually or through an automatic control system, to prevent the damage. An automatic control system for particulate system could also be suggested to prevent the damage during filter failure but this would also demand installation of an additional backup filtration unit to continue the operation while failed unit is bypassed for repair. Considering these factors, the reliability of gas cleaning process at reasonable costs appears to be the biggest challenge for the commercialization of the gasification technologies. A laboratory scale dry gas cleaning unit has been developed and tested at CSIRO to address some of these challenges. This paper illustrates some of the performance results obtained from the tests prior to detailed scale-up studies to be undertaken.

14/00773 Gasification of lignite in a dual fluidized bed gasifier – influence of bed material particle size and the amount of steam

Kern, S. *et al. Fuel Processing Technology*, 2013, 111, 1–13.

The dual fluidized bed steam gasification system, developed by the Institute of Chemical Engineering at Vienna University of Technology, was originally developed for the utilization of woody biomass as feedstock, but during practical operation of the industrial sized plants of this system it turned out that fuel flexibility is the key issue for economic breakthrough. Therefore, gasification tests were carried out with lignite at different operating conditions at the dual fluidized bed pilot plant at Vienna University of Technology. Tests were performed with an input fuel power of $90\,kW_{th}$. Olivine was used as bed material and the applied particle size was 370 and 510 μm. The steam-to-carbon ratio was varied between 1.3 and $2.1\,kg_{H2O}/kg_{carbon}$. In addition to standard online measurements of the permanent gas components of the product gas, impurities like NH_3, H_2S and tar were also measured. It turned out that a lower amount of steam for fluidization caused a better performance of the gasification reactor in terms of product gas yield, carbon conversion and water conversion. The high catalytic activity of the lignite ash was also a reason for the high product gas quality producing low amounts of condensable hydrocarbons, like tar.

14/00774 Gasification of wood in a dual fluidized bed gasifier: influence of fuel feeding on process performance

Kern, S. *et al. Chemical Engineering Science*, 2013, 90, 284–298.

Gasification of wood pellets at a gasification temperature of 850 °C and a fuel power of 90 kW was performed in a dual fluidized bed gasifier. Pure steam was used as a gasification agent at a steam-to-fuel ratio of $0.6\,kg_{H2O}/kg_{fuel,daf}$. One focus of the investigation was the influence of the position at which the solid fuel was fed into the gasifier. In one case the fuel was fed directly into the bubbling fluidized bed while in the second case the fuel was fed from the top onto the bubbling bed. With in-bed feeding much lower tar contents and a higher H_2 content were observed, while with on-bed feeding the amount of product gas generated was significantly higher. A second focus of this test series was the gas composition inside the reactor. To investigate this, gas measurements were carried out at different height levels in the reactor for both fuel feeding options. It was observed that the gas composition changed drastically along the height of the gasifier. A decrease in the H_2 content of about $12\,vol\%_{db}$ was measured from the lowest to the highest sampling point in the gasifier while the contents of higher hydrocarbons, CH_4, C_2H_4, and C_2H_6, increased towards the gasifier outlet.

14/00775 Influence of fuel feeding positions on gasification in dual fluidized bed gasifiers

Wilk, V. *et al. Biomass and Bioenergy*, 2013, 54, 46–58.

An in-bed and an on-bed feeding system are implemented in a dual fluidized bed gasifier in order to investigate the influence of the fuel feeding position on the gasification process. Two bed materials, fresh and used olivine, are used because of their varying catalytic activity. The comparison of in-bed and on-bed feeding of wood pellets shows that in-bed feeding is more favourable, because lower tar concentrations are achieved and the gas composition is closer to water–gas shift equilibrium. Better mixing of bed material and fuel particles occurs with in-bed feeding. The residence time of the gas phase in the fluidized bed is longer in the case of in-bed feeding, and therefore better performance of the gasifier is achieved. Sufficient residence time of the fuel in the bubbling bed is important when a less active bed material is used. More active bed material is capable of compensating for the shorter residence time of the gas phase in contact with bed material during on-bed feeding.

14/00776 Investigation of sulfur-resistant, highly active unsupported MoS_2 catalysts for synthetic natural gas production from CO methanation

Liu, J. *et al. Fuel Processing Technology*, 2013, 110, 249–257.

This paper reports on an enhanced activity of sulfur-resistant methanation catalyst by introducing sulfur powder instead of toxic H_2S in catalyst preparation. Ammonium heptamolybdate (AHM) was a suitable precursor for this catalyst preparation based on consideration of economy and activity. The effect of S/AHM weight ratio and sulfidation atmosphere on catalyst methanation performance was studied and the optimum S/AHM ratio was 3. Sulfidation atmosphere affected not only methanation activity but also the structure and morphology of the catalysts. The catalyst treated in inert atmosphere exhibited relatively the highest methanation activity with CO conversion as high as 88.2%, which was approaching the thermodynamic equilibrium value. The catalysts characterization results indicated that the as-prepared catalyst at S/AHM ratio as 3 had relatively higher specific surface area and larger pore volume than those with other S/

AHM ratio. The MoS_2 particles were poorly crystallized with long and straight multi-layered slabs. For the catalyst treated in nitrogen environment, more weakly-bonded sulfur species existed on the surface and more sulfur vacancies resided on the edge planes of MoS_2 particles, which are considered to be the active sites for methanation.

14/00777 Plant design aspects of catalytic biosyngas conversion to higher alcohols

Atsonios, K. *et al. Biomass and Bioenergy*, 2013, 53, 54–64.

Although biomethanol production has attracted most of the attention in recent years, there is a current trend for the synthesis of higher alcohols (i.e. ethanol, plus C_3–C_4) from biomass gasification. These compounds could be used directly as fuel or fuel additives for octane or cetane number enhancement. These also serve as important intermediates for the chemical industry. In this paper a comparison is performed between the different process configurations a higher alcohols production plant from biomass gasification can take. These options are modelled in Aspenplus^{TM}; all steps and important unit operations are presented with the aim to correctly evaluate the peripheral energy requirements and conclude with the overall thermodynamic limitations of the processes. The differentiation between black liquor and solid biomass gasification, the type of catalyst employed, and the effect of the recycling scheme adopted for the reutilization of unreacted syngas are evaluated. The design has to cope with the limited yields and poor selectivity of catalysts developed so far. The gas cleaning is different depending on the different requirements of the catalysts as far as H_2S purity. The process modelling results reveal that the hydrogenation of CO to higher alcohols is favoured by high pressure, temperature around 325 °C and high reactor residence times. A biorefinery using modified Fisher–Tropsch catalysts (MoS_2) prevail over modified MeOH catalyst (Cu–Zn based) for higher alcohols production. The efficiency of higher alcohols production in higher heating value terms can reach up to 25%.

14/00778 Simulation study on biodiesel production by reactive distillation with methanol at high pressure and temperature: impact on costs and pollutant emissions

Gomez-Castro, F. I. *et al. Computers & Chemical Engineering*, 2013, 52, 204–215.

Recently, a two-step biodiesel production process which uses short-chain alcohols at supercritical conditions has been proposed. In addition, literature reports suggest that the COSMO-SAC thermodynamic model is a suitable alternative for the prediction of vapour–liquid equilibrium for supercritical methanol/methyl esters mixtures. Thus, in this work a simulation study of the two-step supercritical method for the production of biodiesel is performed by using the COSMO-SAC model. Further, alternative system configurations for biodiesel production based on reactive distillation are proposed and their total emissions are compared to those corresponding to the conventional catalytic method. The study demonstrates the benefits of using reactive distillation for the esterification step and discusses the environmental impact of the supercritical production process. It has been found that the intensified alternatives reduce the emissions considerably and, through the reuse of the excess methanol, the emissions level of the supercritical process can be compared to those of the catalytic method.

LNG

14/00779 Cryogenic sandwich-type insulation board composed of E-glass/epoxy composite and polymeric foams

Choi, I. *et al. Composite Structures*, 2013, 102, 61–71.

Liquefied natural gas (LNG) is a clean energy source whose consumption has recently increased greatly due to the failure of a nuclear power plant. LNG is transported with LNG carriers that store LNG at the cryogenic temperature of −163 °C. Because the cargo containment system (CCS) of LNG carriers should be operated for more than 40 years at the cryogenic temperature, its reliability against thermal and mechanical loads should be guaranteed without compromising its thermal insulation performance. For reasons of both mechanical and thermal performance, the faces and cores of conventional insulation boards are made of plywood and high-density (110 kg/m^3) polymeric. In this study, an advanced sandwich-type insulation board composed of E-glass/epoxy composite faces and a low-density polymeric foam core with a composite box configuration was developed to seal a foam blowing gas of low thermal conductivity. The mechanical performance of the advanced sandwich-type insulation board was simulated using the finite element analysis (FEA) software ABAQUS (SIMULIA, USA). The sealing performance of the composite box was also investigated experimentally. Finally, the thermal performance of the advanced sandwich-type insulation board was numerically investigated using thermal conductivity equations.

14/00780 Optimization of a simple LNG process using sequential quadratic programming

Wahl, P. E. *et al. Computers & Chemical Engineering*, 2013, 56, 27–36.

The efficiency of using sequential quadratic programming for the optimization of a PRICO process for the production of liquefied natural gas (LNG) is demonstrated. Most of the returned objective values have been better, and the execution times much lower, than in most previously published work on similar optimization cases. The optimization runs discussed in this paper require around 5 min of execution time.

Hydrogen generation and storage

14/00781 A comparative study on energetic and exergetic assessment of hydrogen production from bioethanol via steam reforming, partial oxidation and auto-thermal reforming processes

Khila, Z. *et al. Fuel Processing Technology*, 2013, 112, 19–27.

Three known types of ethanol reforming processes, ethanol steam reforming (ESR), partial oxidation (POX) and auto-thermal reforming (ATR), are investigated. Favourable operating conditions are identified for each reaction system to maximize the production of hydrogen from bioethanol. Each process consists of three sections: the main reactor (ESR, POX or ATR), the CO clean-up section comprised of the water gas shift reactor and preferential CO oxidation reactor and finally, the purification section. The performances of these processes are evaluated through mass, energy and exergy analyses. The material balances show that the total amount of ethanol required to generate 1 mol of hydrogen is 0.23 mol for the ATR, 0.24 mol for the POX and 0.25 mol for the ESR. The ATR reforming process is shown to have the highest energetic efficiency, i.e. the lowest amount of energy is consumed to produce the same amount of hydrogen from ethanol. Moreover, the ATR process has the best exergetic performance, as it presents the highest ratio of exergy recovered in the hydrogen stream to the total exergy supplied to the system. For all three of the systems, the exergy destruction occurs mainly in the reformer due to the high irreversibility of the reaction.

14/00782 A multiphysics numerical model of oxidation and decomposition in a uranium hydride bed

Kanouff, M. P. *et al. Chemical Engineering Science*, 2013, 91, 212–225.

The reaction of uranium hydride and oxygen gas in a hydrogen storage bed has been studied with multiphysics finite element modelling. The model considers rates of chemical reaction, heat transport, and mass transport within a hydride bed. Three scenarios of oxygen gas injection have been considered and the model predictions are in good agreement with experimental measurements. It was found that, under the conditions studied, uranium hydride and oxygen react quickly, forming U_3O_8 and hydrogen gas. It was also found that oxidation of uranium hydride to U_3O_8 produces significant material swelling which, in the reactor studied, reduces the bed porosity from 0.60 to 0.39, and decreases the permeability by a factor of almost 20. A simple, yet reasonably general, description of the process is proposed which accounts for the major changes in global bed flow properties. This model may be used to better anticipate the effects of air-ingress accidents on uranium hydride storage beds and possibly also to explore design options for uranium hydride-based hydrogen generation systems.

14/00783 Comparative environmental impact and efficiency assessment of selected hydrogen production methods

Ozbilen, A. *et al. Environmental Impact Assessment Review*, 2013, 42, 1–9.

The environmental impacts of various hydrogen production processes are evaluated and compared, considering several energy sources and using life cycle analysis. The results indicate that hydrogen produced by thermochemical water decomposition cycles are more environmentally benign options compared to conventional steam reforming of natural gas. The nuclear-based four-step Cu–Cl cycle has the lowest global warming potential (0.559 kg CO_2-eq per kg hydrogen production), mainly because it requires the lowest quantity of energy of the considered processes. The acidification potential results show that biomass gasification has the highest impact on environment, while wind-based electrolysis has the lowest. The relation is also investigated between efficiency and environmental impacts.

14/00784 Development of novel renewable energy based hydrogen production systems: a comparative study

Dincer, I. and Ratlamwala, T. A. H. *Energy Conversion and Management*, 2013, 72, 77–87.

This paper focuses on a comparative study of five renewable energy based hydrogen production systems. These five systems considered in this regard are (a) Cu–Cl integrated with Kalina cycle (system 1), (b) hybrid sulfur (HyS) cycle integrated with isobutane cycle (system 2), (c) quintuple flash power plant integrated with electrolyser (system 3), (d) heliostat field integrated with steam cycle, organic Rankine cycle (ORC) and electrolyser (system 4), and (d) solar photovoltaic/thermal (PV/T) integrated with triple effect absorption cooling system and electrolyser (system 5). The results obtained here show that energy efficiencies of these five systems are not affected by the rise in ambient temperature. It is also found that among these five systems studied, system 1 performs the best and system 5 ends with the worst. The energy and exergy efficiencies, sustainability index, and energy required to produce unit L/s of hydrogen for system 1 are found to be 59%, 83%, 5.9, and 16.58 kW, respectively.

14/00785 Experimental study on the performance of hydrogen production from miniature methanol–steam reformer integrated with Swiss-roll type combustor for PEMFC

Chein, R.-Y. *et al. Applied Energy*, 2013, 105, 86–98.

A miniature plate-type hydrogen production reactor using methanol as fuel was designed and tested. This reactor is composed of a catalytic combustor, vaporizer, reformer and methanator. All components were fabricated on one piece of rectangular quartz glass plate 50 mm × 44 mm × 7 mm in size. The combustor was fabricated on one side of the glass plate with a Swiss-roll type channel in which the Pt/Al_2O_3 particles were loaded in segmented form to catalyse the combustion. A spiral channel was fabricated on the other side of the plate and divided into three sections: a vaporizer for liquid methanol–water mixture vaporization, a reformer for methanol–steam reforming catalysed by $CuO/ZnO/Al_2O_3$ particles and a methanator for carbon monoxide (CO) removal catalysed by Ru/Al_2O_3 particles. The test results indicated that this reactor successfully produced H_2 and had thermal efficiency ranging from 13% to 35%. The reactor performance depends on the feed rates to the combustor and reformer, respectively. High methanol conversion can be obtained from either a low feed rate to the reformer or a high feed rate to the combustor. However, both cases also produce high CO concentrations. The CO methanation reaction was used to reduce the CO concentration. It was found that the methanation reaction depends greatly on the reactor temperature with high temperature not being favourable to this reaction. High CO conversion and low H_2 consumption with low methanol conversion result when the reaction temperature is low. Thermal management for producing suitable temperature and catalyst activity improvement in high reaction temperature for the methanator are both needed in the integrated reactor design to reduce the CO concentration down to acceptable levels for fuel cell operation.

14/00786 Fabrication and testing of a planar microstructured concept module with integrated palladium membranes

Boeltken, T. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 136–147.

A planar microstructured hydrogen separation module has been fabricated to study the hydrogen permeation through free-standing palladium-based membranes (Pd, PdCu and PdAg) with minimal influence by concentration polarization. The membranes were laser-welded directly between two face-to-face arranged stainless-steel sheets with 10 microchannels each (width × depth × length of the channels: 500 µm × 300 µm × 2 cm). Single gas hydrogen and mixed gas permeation experiments (H_2/N_2) were conducted between 300 and 400 °C. The permeabilities and activation energies of the membranes in this temperature range were calculated. The 12.5 µm thick membrane was successfully tested up to 650 kPa, indicating that the microchannel plates provide a good mechanical support even for very thin membranes. However, settling of the film into the microchannels on the permeate side was observed due to the overpressure on the retentate side suggesting even finer channels and eventually the use of an additional porous support for very high differential pressure. The concentration polarization effects in the membrane module were evaluated in terms of the film effectiveness factor η which is a familiar concept from heterogeneous catalysis. It could be shown that the microchannel configuration effectively decreases concentration polarization.

14/00787 Numerical analysis of hydrogen generation in a BWR during a severe accident

Valdés-Parada, F. J. *et al. Chemical Engineering Research and Design*, 2013, 91, (4), 614–624.

The aim of this work is to study the behaviour of the temporal evolution of the distributions of the hydrogen concentration and temperatures profiles in the core of the boiling water reactor (BWR) during a severe accident. The core of the BWR is considered as an effective medium where the fuel assembly in the core consists of arrays of in-line fuel rod. The governing effective-medium equations for momentum, heat and mass transfer in terms of effective transport coefficients that capture the essential features of the in-line rods assembly were computed using a computational fluid dynamics method. The dependence of the evolution of the dimensionless hydrogen concentration and temperatures profiles with Péclet and Biot numbers show the ability of the effective medium for accurately describing the transport phenomena for BWR during severe accident.

14/00788 Optimal production of renewable hydrogen based on an efficient energy management strategy

Ziogou, C. *et al. Energy*, 2013, 55, 58–67.

This work presents the development of a flexible energy management strategy (EMS) for a renewable hydrogen production unit through water electrolysis with solar power. The electricity flow of the unit is controlled by a smart microgrid and the overall unattended operation is achieved by a supervisory control system. The proposed approach formalizes the knowledge regarding the system operation using a finite-state machine which is subsequently combined with a propositional-based logic to describe the transitions among various process states. The operating rules for the integrated system are derived by taking into account both the operating constraints and the interaction effects among the individual subsystems in a systematic way. Optimal control system parameter values are obtained so that a system performance criterion incorporating efficient and economic operation is satisfied. The resulted EMS has been deployed to the industrial automation system that monitors and controls a small-scale experimental solar hydrogen production unit. The overall performance of the proposed EMS in the experimental unit has been evaluated over short-term and long-term operating periods resulting in smooth and efficient hydrogen production.

14/00789 Prolonged hydrogen production by *Nostoc* in photobioreactor and multi-stage use of the biological waste for column biosorption of some dyes and metals

Mona, S. *et al. Biomass and Bioenergy*, 2013, 54, 27–35.

Hydrogen production by *Nostoc linckia* was studied using both free and alginate immobilized biomass of the cyanobacterium in separate lab-scale photobioreactors (PBRs). Hydrogen production rates improved significantly when immobilized cyanobacterial biomass was used in PBR and the production continued up to 25 days by maintaining required anoxic conditions and carbohydrate supplement. Average hydrogen production rate over 25 days was 132 $\mu molH_2/h/mg$ Chl a. The biological waste from the PBRs was utilized for sequestration of two toxic heavy metals (chromium and cobalt) and carcinogenic dyes (Reactive Red 198 and Crystal Violet) from aqueous solutions in packed-bed column. From the PBR containing free *N. linckia* cells, the spent biomass was collected after 7 days, dried and immobilized in alginate matrix, and used as a biosorbent for optimizing bed height and flow rate of the column. Breakthrough capacity of the packed-bed column was determined and breakthrough curves were analysed using the BDST model. Three PBRs containing immobilized cyanobacterial biomass were run for 5, 15 and 25 days, and the biological waste collected at the end of the operation was used for biosorption studies under optimized conditions (bed height, 25 cm; flow rate, 3 mL/min). Biosorption efficiency of the waste biomass was found to be influenced by the operation time of the hydrogen photobioreactor.

14/00790 Promotion of H_2 production by microwave-assisted treatment of water hyacinth with dilute H_2SO_4 through combined dark fermentation and photofermentation

Cheng, J. *et al. Energy Conversion and Management*, 2013, 73, 329–334.

Water hyacinth was treated with microwave-assisted dilute H_2SO_4 to improve saccharification before enzymatic hydrolysis and H_2 production during dark fermentation. A maximum reducing sugar (RS) yield of 64.4 g/100 g total volatile solid (TVS) (96.1% of the theoretical RS yield) was achieved when water hyacinth was treated through microwave heating with 1% dilute H_2SO_4 for 15 min at 140 °C and then enzymatically hydrolysed for 72 h. During enzymatic hydrolysis, glucose was efficiently produced from the hydrolysis of cellulose that resulted from the disruption of the lignocellulosic structure of water hyacinth after microwave-assisted H_2SO_4 treatment. When the hydrolysed water hyacinth was inoculated with H_2-producing bacteria to produce H_2 during dark fermentation, a maximum H_2 yield of 112.3 ml/g TVS was obtained. The major sugar compositions in the residual solution from dark fermentation were xylose and cellobiose (total RS utilization efficiency: 88.5%). Through a combination of dark fermentation and photofermentation, the maximum H_2 yield from water hyacinth was significantly increased from 112.3 ml/g TVS to 751.5 ml/g TVS, which is 75.2% of the theoretical H_2 yield.

14/00791 Recent advances on membranes and membrane reactors for hydrogen production

Gallucci, F. *et al. Chemical Engineering Science*, 2013, 92, 40–66.

Membranes and membrane reactors for pure hydrogen production are widely investigated not only because of the important application areas of hydrogen, but especially because mechanically and chemically stable membranes with high perm-selectivity towards hydrogen are available and are continuously further improved in terms of stability and hydrogen flux. Membrane reactors are (multiphase) reactors integrating catalytic reactions (generally reforming and water gas shift reactions for hydrogen production) and separation through membranes in a single unit. This combination of process steps results in a high degree of process integration/intensification, with accompanying benefits in terms of increased process or energy efficiencies and reduced reactor or catalyst volume. The aim of this review is to highlight recent advances in hydrogen selective membranes (from palladium-based to silica and proton conductors) along with the advances for the different types of membrane reactors available (from packed bed to fluidized bed, from micro-reactors to bio-membrane reactors). In addition, the application of membrane reactors for hydrogen production from different feedstock is also discussed.

14/00792 Scaled-up synthesis of nanostructured Mg-based compounds and their hydrogen storage properties

Liu, T. *et al. Journal of Power Sources*, 2013, 227, 86–93.

In a manner different to conventional methods, the authors have produced nanoparticles of Mg, Fe, Co, Ni, Cu and other metals by hydrogen plasma metal reaction (HPMR) at a semi-industrial scale. Using these elemental nanoparticles as raw materials, nanostructured Mg-based compounds with high purity including Mg_2Ni, Mg_2Co, Mg_2Cu and Mg_2FeH_6 are further synthesized by gas–solid reaction in much mild conditions. The Mg_2Ni nanoparticles of 50 nm can be prepared at 523 K under 4 MPa H_2. The formation mechanisms of the elemental nanoparticles during HPMR and the nanostructured Mg-based compounds during gas–solid reaction are discussed. The nanostructure of these samples greatly enhances the kinetic properties of hydrogen absorption and desorption. The Mg_2Ni nanoparticles can absorb hydrogen and saturate at $0.95\,\mathrm{H\,M^{-1}}$ (the number of hydrogen atoms per metal atom) in several minutes at 493 K. The sorption kinetics of the nanostructured Mg_2Ni is almost stable during 10 cycles. The thermodynamic properties of these nanostructured Mg_2M are improved slightly.

14/00793 SiO_2-supported ferromagnetic catalysts for hydrogen generation from alkaline $NaBH_4$ (sodium borohydride) solution

Shih, Y.-J. *et al. Energy*, 2013, 54, 263–270.

Ferromagnetic elements Fe, Ni and Co were immobilized on the porous SiO_2 to catalyse the hydrogen generation from aqueous alkaline $NaBH_4$ (sodium borohydride). The porous SiO_2 was prepared by silica-surfactant self-assembly and the ferromagnetic catalyst was prepared by chemical reduction. The ferromagnetic catalysts were characterized using thermogravimetry/differential thermal analysis, BET, X-ray powder diffraction, environmental scanning electron microscope/energy dispersive spectroscopy, X-ray photoelectron spectroscopy and vibration sample magnetometer measurements. The surface area of porous SiO_2 was affected by the molecular weight of surfactant. The relative catalytic activities in the generation of hydrogen from alkaline $NaBH_4$ solution follow the order $Co/SiO_2 > Ni/SiO_2 > Fe/SiO_2$. The rates of hydrogen generation using Co/SiO_2, Ni/SiO_2 and Fe/SiO_2 catalysts in 20 ml of 5 wt% $NaBH_4$ solution at 313 K were 8701, 307 and $130\,\mathrm{ml\,min^{-1}\,g^{-1}}$-metal, respectively. It is found that the degree of metal-oxidation and crystal structure affected the catalytic activity. The hydrogen generation of $NaBH_4$ in alkaline solution increased with increasing cobalt loading, of which the activation energy was $59 \pm 2\,\mathrm{kJ\,mol^{-1}}$.

14/00794 Solar hydrogen production via pulse electrolysis of aqueous ammonium sulfite solution

Huang, C. *Solar Energy*, 2013, 91, 394–401.

A long-standing challenge for hydrogen production via solar water splitting is the efficiency of converting solar energy to hydrogen chemical energy. Thermolysis, photocatalysis and electrolysis are three basic solar water splitting processes that utilize solar thermal, photonic and electrical energies. A technology using a combination of these processes can utilize a wider spectrum of solar radiation, thereby enhancing the efficiency of solar energy conversion. Due to the simplicity and maturity of photovoltaic (PV) cells and electrolyser cells, solar hydrogen production via PV cells plus water electrolysis has been implemented and widely used as a bench mark process. The present study focuses on solar hydrogen production via direct current pulse electrochemical oxidation of aqueous ammonium sulfite solutions, one important step in solar sulfur–ammonia (S-NH_3) thermochemical water splitting cycles. The results show that pulsating electrolysis enhances the efficiency of hydrogen production. The effects of pulsating parameters (such as pulsating on time and off time, frequency and duty cycle) on hydrogen evolution rates are discussed in detail.

14/00795 Towards hydrogen safety engineering for reacting and non-reacting hydrogen releases

Saffers, J.-B. and Molkov, V. V. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 344–350.

Hydrogen safety engineering (HSE) is the application of scientific and engineering principles to the protection of life, property and environment from adverse effects of incidents/accidents involving hydrogen. Validated engineering tools for calculation of flammable envelope size and hydrogen jet flame length are of importance for calculation of safety distances. This paper compares the University of Ulster (UU) methodology for calculation of safety distances based on the similarity law for concentration decay in non-reacting jet, and the approach given in the standard NFPA 55. It is shown that NFPA 55 can overestimate an axial distance to the lower flammability limit up to 160%. Two correlations for hydrogen jet flame length are compared. One approach (Sandia National Laboratories) correlates the dimensionless flame length with the flame Froude number, and another (UU) associates the flame length with a new similarity group, which is a product of mass flow rate and nozzle diameter. Both approaches are compared against 123 experimental data on expanded and under-expanded jet flames. In the typical for hydrogen applications momentum-controlled regime the first approach has scattering of experimental data 50% while the second approach gives only 20% and thus is preferable for the use by hydrogen safety engineers.

04 BY-PRODUCTS RELATED TO FUELS

14/00796 A review on carbon dioxide capture and storage technology using coal fly ash

Wee, J.-H. *Applied Energy*, 2013, 106, 143–151.

This work reviews the availability and the potential of the carbon capture and storage (CCS) technology using coal fly ash (FA). Because the technology can be effectively applied on-site to coal fired power plants and as FA contains sufficient alkali components, the technology may be another option of CCS technology to a limited extent. The technology can be divided into wet and dry processes. In the former, the available components for CCS in FA are leached into solution by the solvent where they are subsequently consumed for carbonation to store CO_2. Particularly, the CO_2 storage capacity of CaO-enriched FA solution mixed with brine under high pressure may be equal to or greater than the true CO_2 emission reduction achieved by applying FA as a cement additive. In the dry process, FA can be used as a direct support or as the raw material of the sorbent supports for CO_2 capture. The dry process is effectively applied for CO_2 capture rather than storage because the sorbents should be regenerated. Another advantage of the technology is the stabilization of the harmful components present in FA, which are mostly co-precipitated with carbonated FA during the process.

14/00797 Characteristics of high-water-uptake activated carbon/Nafion hybrid membranes for proton exchange membrane fuel cells

Chien, H.-C. *et al. Journal of Power Sources*, 2013, 226, 87–93.

A cost-effective and high-throughput method for producing high-water-uptake membranes is developed by combining high-porosity and superior-surface-area activated carbon with Nafion. The resultant activated carbon/Nafion hybrid composite exhibits high water uptake and an improved proton conductivity, which can be exploited in a proton exchange membrane fuel cell (PEMFC). This hybrid membrane displays a superior performance to that of the commercial Nafion 211 when used in fuel-cell measurements. Electrochemical impedance spectroscopy is used to simulate the changes in resistance during the operation of the fuel cells and conclusively explains the improved performance of the composite membranes.

14/00798 Characterization of a regenerable sorbent for high temperature elemental mercury capture from flue gas

Scala, F. *et al. Fuel*, 2013, 108, 13–18.

Thus study has developed a regenerable synthetic sorbent based on manganese oxides (12% w/w) impregnated on high surface area γ-alumina and supported as a thin layer (40 μm) onto cordierite honeycomb monoliths (400 cpsi). Such structured sorbents are well suited for flow-through exhaust gas treatment associated with very low pressure drop. Elemental mercury capture experiments were carried out in a lab-scale quartz reactor in air at temperatures ranging from 50 to 350 °C, Hg concentration in the range $50–250\,\mu\mathrm{g/m^3}$, GHSV = $3.6 \times 10^5\,\mathrm{h^{-1}}$. A kinetic and capacity characterization of the sorbent was conducted, giving insight on the controlling mechanisms of the mercury capture process. Structured MnO_x sorbent performed satisfactorily up to 300 °C, the performance decaying dramatically above this temperature when desorption of elemental Hg became predominant. Temperature programmed desorption experiments after mercury uptake on the sorbent, showed that the sorbent could be completely regenerated at a temperature as low as 500 °C. Repeated cycles of mercury adsorption/desorption did not lead to any significant reduction of the sorbent capacity towards mercury uptake. No significant mercury oxidation in the gas phase was observed under the operating conditions used in the experiments.

14/00799 Geochemical characterization of arsenic-rich coal-combustion ashes buried under agricultural soils and the release of arsenic

Veselská, V. *et al. Applied Geochemistry*, 2013, 33, 153–164.

A combination of geochemical and mineralogical methods was used to determine the concentrations, mobility, and sources of As in coal-combustion ashes and soils in the vicinity of a thermal power plant at Nováky, central Slovakia. Fresh lagooned ash, ashes buried under agricultural soils for 45 years, and the overlying soils, contain high concentrations of As ranging from 61 to 1535 mg/kg. There are no differences in the water extractable percentages of As between the fresh lagooned ash and buried ashes, which range from 3.80% to 6.70% of the total As. This small amount of As may perhaps reside on the surfaces of the ash particles, as postulated in the earlier literature, but no evidence was found to support this claim. Electron microprobe analyses show that the dominant primary As carriers are the aluminosilicate glasses enriched in Ca and Fe. The acid NH_4^+-oxalate extraction hints that the oxyhydroxides of Si, Al, and Fe are the most probable secondary carriers of labile As. The X-ray absorption spectroscopy (XAS) analyses show that As in the lagooned and buried ashes occurs mostly as As(V). The long-term burial of the coal-combustion ash under agricultural soil did not cause any major change of its chemical composition or As lability compared to the fresh lagooned ash.

14/00800 High-pressure separation of CH_4/CO_2 using activated carbon

Grande, C. A. *et al. Chemical Engineering Science*, 2013, 89, 10–20.

Activated carbon was evaluated as selective adsorbent for separation of CO_2 from CO_2/CH_4 mixtures with special focus on high-pressure applications. Adsorption equilibrium of pure gases was recorded at three different temperatures up to 8000 kPa for CH_4 and 5000 kPa for CO_2. Multi-site Langmuir, Virial and Sips models were used to fit the equilibrium data and predict multi-component equilibrium. Binary adsorption equilibrium measurements and binary breakthrough curves with mixtures of 10 and 20% CO_2 balanced with CH_4 were carried out at three different pressures: 500, 2500 and 5000 kPa. A one-dimensional mathematical model including mass, energy and momentum transport was used to describe the curves using a non-ideal gas behaviour equation. CO_2 is more selectively adsorbed than CH_4 in the activated carbon used in this study. The binary adsorption capacity obtained from binary breakthrough curves could only be well described by the Sips model. In all breakthrough curves, a small effect of the film mass transfer could be observed, particularly at higher pressures where this effect is more pronounced. The significant adsorption of CH_4 may limit the application of this adsorbent for natural gas upgrading.

14/00801 Role of additives in improved thermal activation of coal fly ash for alumina extraction

Guo, Y. *et al. Fuel Processing Technology*, 2013, 110, 114–121.

The extraction of alumina from coal fly ash is a good direction for its value-added utilization. The presence of the inert matters with high degree of polymerization, such as mullite and other aluminosilicates, makes the reactivity of coal fly ash very poor. The activation of coal fly ash is necessary before its utilization. The thermal activation calcination with the addition of NaOH and Na_2CO_3 was carried out in this research. The results showed that the addition of NaOH and Na_2CO_3 improved the alumina extraction evidently. The maximum alumina extraction reached ~60% when calcination at 600–900 °C with the addition of NaOH and that could reach 82% at 900 °C with the addition of Na_2CO_3. Detailed analysis and characterization was carried out by using thermal gravimetric and differential scanning calorimetric analysis and X-ray diffraction. The results indicated that NaOH and Na_2CO_3 facilitated the decomposition of the polymeric phases. At lower temperatures (< 600 °C), NaOH played a main role while Na_2CO_3 did at higher temperatures (> 700 °C). As a result, the mixed additives containing NaOH and Na_2CO_3 made alumina extraction attain 95% at 700 °C.

14/00802 Sulfur removal property of activated-char-supported Fe–Mo sorbents for integrated cleaning of hot coal gases

Yu, J. *et al. Fuel*, 2013, 108, 91–98.

An integrated hot coal gas cleaning process is proposed with emphasis on simultaneous removal of multiple impurities including sulfur containing species, NO_x precursors, mercury and tarry materials. Activated-char-supported sorbents were synthesized by gasifying Fe and Mo impregnated Chinese lignite coal in steam (15%, vol) at 1100 K for 15 min. Sulfur removal properties of the sorbent samples were examined by sulfidation experiments using simulated coal gases (with 4700 ppmv H_2S and 470 ppmv COS) at a space velocity of $1000\,h^{-1}$ using a fixed-bed quartz reactor at the temperature range of 673–873 K. The SEM with EDS and XRD were used to examine the physical and chemical changes in the sorbents during sulfidation. The active metal oxides components were dispersed in the char matrix as nano-size particles resulting in a high reactivity of the sorbents towards H_2S and COS contained in coal gases. Under the conditions in this study, the sorbents can effectively remove H_2S and COS from the simulated coal gases with high efficiency. Sulfur removal is influenced by the level of iron-loading. The presence of Mo along with Fe in the char-supported sorbents can significantly increase the desulfurization efficiency.

05 NUCLEAR FUELS

Scientific, technical

14/00803 A physical model for evaluating uranium nitride specific heat

Baranov, V. G. *et al. Journal of Nuclear Materials*, 2013, 434, (1–3), 248–251.

Nitride fuel is one of perspective materials for the nuclear industry. But unlike the oxide and carbide uranium and mixed uranium–plutonium fuel, the nitride fuel is less studied. In this study, uranium nitride specific heat data was analysed and the criterion that the specific heat model should satisfy specified. The model density of states for uranium nitride was constructed within Debye and Einstein models, taking into account UN phonon spectrum experimental data. Physically founded formula for calculation of uranium nitride specific heat was proposed and the uranium nitride specific heat is theoretically calculated. It is shown that temperature dependence of uranium nitride specific heat calculated in this work agrees well with the experimental data.

14/00804 Active interrogation of nuclear materials using $LaBr_3$: Ce detectors

Omer, M. *et al. Energy Procedia*, 2013, 34, 50–56.

Active interrogation in ^{235}U was demonstrated with LaBr3 : Ce scintillation detectors using the nuclear resonance fluorescence (NRF) technique. An NRF experiment was performed at the high-intensity y-ray source facility using quasi-monochromatic circularly or linearly polarized y-ray beams. Photons scattered at 90° relative to the incident beam were detected with two different sizes of cylindrical $LaBr_3$: Ce detectors. Clear NRF peaks at 1733 and 1815 keV corresponding to de-excitations to the ground state and/or low-lying levels in ^{235}U were observed within 77 minutes of beam time even under the high background due to the self-activity of $LaBr_3$: Ce and the radioactive decay of ^{214}Bi nuclei existing in the ^{235}U target. This study shows the possibility of using the $LaBr_3$: Ce detector to perform NRF experiments, promoting many options for the inspection of special nuclear materials.

14/00805 Assessment of neutron irradiation effects on RAFM steels

Gaganidze, E. and Aktaa, J. *Fusion Engineering and Design*, 2013, 88, (3), 118–128.

The objective of the current work is assessment of the effects of neutron irradiation on the mechanical properties of blanket and diverter materials of a future fusion energy generation demonstration power plant (DEMO). The emphasis is put on the review of the tensile, Charpy impact and fracture toughness properties of EUROFER97 and EUROFER ODS (9%Cr) (reduced activation ferritic/martensitic, RAFM) steels irradiated up to a displacement damage dose of 80 displacements per atom (dpa) in order to address: (i) irradiation dose dependence of mechanical properties, (ii) irradiation temperature dependence of the mechanical properties and (iii) helium effects on the mechanical properties. The assessment will be used to give recommendations on the operating temperature range for the first wall and helium-cooled breeding blanket materials and to identify needs for the research and development of structural materials.

14/00806 Characterising highly active nuclear waste simulants

Paul, N. *et al. Chemical Engineering Research and Design*, 2013, 91, (4), 742–751.

Reprocessing of spent nuclear fuel produces a highly active liquor (HAL) waste stream, which is typically stored over extended periods of many years in waste tanks equipped with extensive heat exchange capability. Over time, particulates are known to precipitate from the HAL within these tanks. Particle simulants provide a route for understanding the physical behaviour of these HAL solids under different agitation and transfer conditions. Particle and dispersion characterization techniques are used here to understand the behaviour of two types of simulant HAL solids, namely caesium phosphomolybdate (CPM) and zirconium molybdate (ZM), in dispersion. Distinct properties are established for CPM and ZM and compared to a common oxide particle material titanium dioxide (TiO_2). The results of this study highlight the influence of key aspects of the HAL particulates, such as size and shape, on relevant solid–liquid properties such as sedimentation and rheology. The influence of bulk liquid properties such as electrolyte concentration and pH is also investigated. The results indicate various possible behaviours within the tanks which may impact the storage, remobilization and pipeline transport of this class of nuclear waste.

14/00807 Characterization of time varying thermophysical property of a surface layer: numerical feasibility for JET tokamak tiles

Gaspar, J. *et al. International Journal of Heat and Mass Transfer*, 2013, 56, (1–2), 147–157.

The present paper deals with the thermal characterization of the surface carbon layer (SCL) usually poorly attached to the plasma-facing component (PFC) inside the nuclear fusion machines (tokamak). A non-linear unsteady calculation combined with the conjugate gradient method and the adjoint state is achieved in order to characterize *in situ* the time variation of the thermal resistance R_{th} of a surface layer. A numerical feasibility is presented with a realistic virtual experiment design. The accuracy of the method is examined by using simulated exact and inexact infrared measurements obtained on the SCL surface. The advantages of applying the conjugate gradient method with the adjoint state in the present study, are that no prior information is needed on the time variation and the initial guess of the unknown thermal resistance.

14/00808 Construction time of PWRs

Moreira, J. M. L. *et al. Energy Policy*, 2013, 55, 531–542.

The construction time of pressurized water reactors (PWRs) is studied considering the published data of nuclear power plants in the world. For the 268 PWRs in operation in 2010, the mode of the construction time distribution is around 5–6 years, and 80% of the plants were built in less than 120 months. To circumvent the problem of comparing plants with different size, the authors normalized the construction time to plants with 1 GW. The authors restricted the analysis to 201 PWRs which suffered less from external factors that were beyond the control of the management from 1965 to 2010. The results showed that the normalized construction time did not increase over the years and nor with the plants' gross power level. The learning rate of the industry regarding normalized construction times showed a reduction with 95% confidence level of about 0.56 ± 0.07 months for each 10 GW of installed capacity. Over the years the normalized construction time decreased and became more predictable. The data showed that countries with more centralized regulatory, construction and operation environments were able to build PWRs in shorter times. Countries less experienced with the nuclear technology built PWRs in longer times.

14/00809 Design method of flow distribution in nuclear reactor systems

Wang, J. *Chemical Engineering Research and Design*, 2013, 91, (4), 595–602.

Flow distribution is encountered widely in nuclear reactor systems including distribution of liquid coolant, feedwater or steam sparger, and high energy fluid into condenser of steam turbine. Distributors with parallel ports or openings are common designs which may be very sensitive to variations of structure and dimensions of a manifold and its ports. Non-uniformity of flow distributions causes largely potential malfunction and poor efficiency, even failures. In this paper, a theoretical model was developed for a tapered distributor. Analytical solutions were obtained for evaluation of influence of operating conditions and structures and dimensions of distributor and ports on flow distributions. Structural parameters were identified and hydraulic characteristics were analysed. The orifices, slope and tube protrusion are useful for improvement of the flow distributions. The uniformity of the flow distributions can be improved about 10–60% by fitting orifice rings or tube protrution with a range of the minor loss coefficients: 0.5–3. Finally design criteria were suggested for industrial applications. This provides a simple and easy-to-use tool for design of the flow distribution in nuclear reactors and power boilers.

14/00810 Development of ITER tritium transport package

Lee, S. *et al. Fusion Engineering and Design*, 2013, 88, (3), 136–144.

To have a tritium supply to the International Thermonuclear Experimental Reactor (ITER) fusion reactor, tritium needs to be transported from tritium production sites, mainly the CANDU-type reactor sites to the tritium plant building of the ITER. The Korean Atomic Energy Research Institute was commissioned to develop the tritium transport package for the ITER and the first stage of the development has now been completed. The developed package was designed to carry 70 g of tritium and classified as a type B(U) package, which should comply with the requirements stipulated in the #International Atomic Energy Agency regulations for the transportation of radioactive materials. The package is composed of a storage vessel, a containment vessel, an overpack and an aluminium liner, which is a unique feature of the package. The aluminium liner, placed between the storage vessel and the containment vessel, is for containment control under the repetitive use of the package. The package has sufficient pressure resistance for 5 years' in-site storage. Structural and thermal integrity under hypothetical accident conditions has been demonstrated through a series of analyses.

14/00811 Development of the hot isostatic press manufacturing process for monolithic nuclear fuel

Crapps, J. *et al. Nuclear Engineering and Design*, 2013, 254, 43–52.

Finite element simulation and experimentation were used to understand and improve the hot isostatic press (HIP) manufacturing process for monolithic fuel plates. As expected, it was found that the simulation results were sensitive to the temperature dependence of the material properties. For the steady-state simulations considered, it is important to use material properties close to the relevant process temperature. Furthermore, plasticity must be taken into account in order to obtain accurate predictions. The simulation results for the HIP process are largely insensitive to the value of the friction coefficient, but a small friction coefficient is required to assure good qualitative agreement with experiment. Most importantly, the simulations indicate that extending the aluminium cladding to fill the space between the strongbacks prevents the aluminium cladding extrusion into the space between strongbacks and allows for a more uniform distribution of normal stresses along the fuel-cladding interface. The study verified experimentally that this change in geometry leads to flat clad-fuel products. Furthermore, the plastic deformation of the steel strongbacks is dramatically reduced when the aluminium cladding is extended to fill the HIP can, and these strongbacks can be reused in subsequent HIP runs.

14/00812 Dynamic leaching studies of 48 MWd/kgU UO_2 commercial spent nuclear fuel under oxic conditions

Serrano-Purroy, S. *et al. Journal of Nuclear Materials*, 2013, 434, (1–3), 451–460.

The leaching of a high-burn-up spent nuclear fuel (48 MWd/kgU) has been studied in a carbonate-containing solution and under oxic conditions using a continuously stirred tank flow-through reactor (CSTR). Two samples of the fuel, one prepared from the centre of the pellet (labelled CORE) and another one from the fuel pellet periphery, enriched with the so-called high burn-up structure (HBS, labelled OUT) have been used. For uranium and actinides, the results showed that U, Np, Am and Cm gave very similar normalized dissolution rates, while Pu showed slower dissolution rates for both samples. In addition, dissolution rates were consistently two to four times lower for OUT sample compared to CORE sample. Considering the fission products release the main results are that Y, Tc, La and Nd dissolved very similar to uranium; while Cs, Sr, Mo and Rb have up to 10 times higher dissolution rates. Rh, Ru and Zr seemed to have lower dissolution rates than uranium. The lowest dissolution rates were found for OUT sample. Three different contributions were detected on uranium release, modelled and attributed to oxidation layer, fines and matrix release.

14/00813 Effect of intergranular failure on the critical fracture stress and the fracture toughness of degraded reactor pressure vessel steel

Wu, S. J. and Cao, L. W. *International Journal of Pressure Vessels and Piping*, 2013, 101, 23–29.

The fracture mechanisms in the ductile-to-brittle transition (DBT) region of the undegraded and degraded A533B steel have been studied. Two mechanisms were observed in the initial stage of the DBT region: transgranular cleavage fracture and intergranular fracture. Factors affecting the proportion of intergranular fracture on the fracture surface have been investigated by four-point-bending (4PB) mechanical tests, scanning electron microscopy observation and statistical fractographic analysis. The effect of intergranular fracture on the critical fracture stress has been discussed and an empirical equation for the mixed critical cleavage/intergranular fracture stress is proposed. Finally, attention is also drawn to the interesting difference in the intergranular fracture percentages shown on the fracture surfaces of fracture toughness test specimens.

14/00814 Effects of pellet-to-cladding gap design parameters on the reliability of high burnup PWR fuel rods under steady state and transient conditions

Tas, F. B. and Ergun, E. *Energy Conversion and Management*, 2013, 72, 88–93.

As an important improvement in the light water nuclear reactor operations, the nuclear fuel burn-up rate has increased in recent decades and this increase causes heavier duty for the nuclear fuel. Since the high burn-up fuel is exposed to very high thermal and mechanical stresses and since it operates in an environment with high radiation for about 18-month cycles, it carries the risk of losing its integrity. In this study; it is aimed to determine the effects of pellet–cladding gap thickness and gap pressure on reliability of high burn-up nuclear fuel in pressurized water reactors (PWRs) under steady-state operation conditions and suggest optimum values for the examined parameters only and validate these suggestions for a transient condition. In the presented study, fuel performance was analysed by examining the effects of pellet–cladding gap thickness and gap pressure on the integrity of high burn-up fuels. This work is carried out for a typical Westinghouse type PWR fuel. The steady state conditions were modelled and simulated with FRAPCON-3.4a steady-state fuel performance code and the FRAPTRAN-1.4 fuel transient code was used to calculate transient fuel behaviour. The analysis included the changes in the important nuclear fuel design limitations such as the centreline temperature, cladding stress, strain and oxidation with the change in pellet–cladding gap thickness and initial pellet–cladding gap gas pressure. In addition, the analysis were performed to observe whether the changes in pellet–cladding gap thickness and the gap gas pressure can substitute each other or not when it comes to design changes in nuclear fuel design to increase burn-up. Also, the verification of the suggestions for pellet–cladding gap thickness was performed under transient conditions. The results of these analyses showed the favourable design change for the pellet–cladding gap for heavier fuel duty conditions.

14/00815 Hydrogen behaviors in molybdenum and tungsten and a generic vacancy trapping mechanism for H bubble formation

Sun, L. *et al. Journal of Nuclear Materials*, 2013, 434, (1–3), 395–401.

This study investigates the trapping behaviours of hydrogen (H) in molybdenum (Mo) and tungsten (W) using a first-principles method with a zero point energy correction as well as the molecular dynamics (MD) method. The H trapping is found to generally satisfy the 'optimal charge density' rule at the vacancy, and a monovacancy is shown to simultaneously trap 14 H with a H_2 molecule formed at the vacancy centre in both Mo and W. On the other hand, the MD simulation shows the temperature decreases the number of trapped H at the vacancy. A generic vacancy trapping mechanism for H bubble formation in metals is also proposed. The H atoms will first saturate the internal surface of the vacancy (or other vacancy-type defects) to form a 'screening layer', which can screen the interaction between the further trapped H and the surrounding metal atoms. This leads to the formation of H_2 molecule at the vacancy centre, which can be considered as the preliminary stage of H bubble nucleation.

14/00816 Laser damage thresholds of ITER mirror materials and first results on in situ laser cleaning of stainless steel mirrors

Wisse, M. *et al. Fusion Engineering and Design*, 2013, 88, (5), 388–399.

A laser ablation system has been constructed and used to determine the damage threshold of stainless steel, rhodium and single-, poly- and nanocrystalline molybdenum in vacuum, at a number of wavelengths between 220 and 1064 nm using 5 ns pulses. All materials show an increase of the damage threshold with decreasing wavelength below 400 nm. Tests in a nitrogen atmosphere showed a decrease of the damage threshold by a factor of two to three. Cleaning tests have been performed in a vacuum on stainless steel samples after applying mixed Al/W/C/D coatings using magnetron sputtering. *In situ* X-ray photoelectron spectroscopy analysis during the cleaning process as well *ex situ* reflectivity measurements demonstrate near complete removal of the coating and a substantial recovery of the reflectivity. The first results also show that the reflectivity obtained through cleaning at 532 nm may be further increased by additional exposure to ultraviolet light, in this case 230 nm, an effect which is attributed to the removal of tungsten dust from the surface.

14/00817 Mechanical behavior of fluoroelastomer considering long term ageing

Sinha, N. K. *et al. Nuclear Engineering and Design*, 2013, 254, 89–96.

Stress-elongation behaviour of a Viton A-401C-based compound established for backup seals of a 500 MW(e) prototype fast breeder reactor is described. Stress-softening effects are negligible during room temperature (RT) or 110 °C measurements on unaged samples at strain rates of 50 and 500 mm/min because of low filler content. Relaxation is observed during RT property determination at lower strain rate. Stiffening of behaviour at 50 mm/min and 110 °C is attributed to the Joule–Gough effect and absence of relaxation because of increased molecular chain mobility. The two zone stress-elongation behaviour (determined by chemical cross-links up to ~85% strain and by ionic interactions beyond) propounded in the article by combining air-aged specimen data (32 weeks at 140/170/200 °C) provides a behaviour map of bisphenol cured, low filler, fluoroelastomers made of vinylidene fluoride and hexafluoropropylene. This could be extended to peroxide-cured fluorocarbon rubbers for verifications and providing qualified compounds of better grades for critical nuclear elastomeric sealing applications.

14/00818 Metal matrix composite fuel for space radioisotope energy sources

Williams, H. R. *et al. Journal of Nuclear Materials*, 2013, 433, (1–3), 116–123.

Radioisotope fuels produce heat that can be used for spacecraft thermal control or converted to electricity. They must retain integrity in the event of destruction or atmospheric entry of the parent spacecraft. Addition of a metal matrix to the actinide oxide could yield a more robust fuel form. Neodymium(III) oxide (Nd_2O_3)–niobium metal matrix composites were produced using spark plasma sintering; Nd_2O_3 is a non-radioactive surrogate for americium(III) oxide (Am_2O_3). Two compositions, 70 and 50 wt% Nd_2O_3, were mechanically tested under equibiaxial (ring-on-ring) flexure according to ASTM C1499. The addition of the niobium matrix increased the mean flexural strength by a factor of about two compared to typical ceramic nuclear fuels, and significantly increased the Weibull modulus to over 20. These improved mechanical properties could result in reduced fuel dispersion in severe accidents and improved safety of space radioisotope power systems.

14/00819 Modeling lateral contact constraints among CANDU fuel rods

Yu, S. D. and Hojatie, H. *Nuclear Engineering and Design*, 2013, 254, 16–22.

An effective procedure based on the linear complementary problem formulation is presented in this paper to deal with lateral contact constraints among a system of closely packed and parallel fuel rods at a cross-section where spacer pads and bearing pads are introduced. The total number of potential contact constraints exceeds the number of available degrees of freedom. Numerical results for an example application involving deformations of seven rods at the midspan cross-section indicate that the proposed procedure is accurate and robust. The scheme is currently being implemented into a computer code for computing vibration of CANDU®2 fuel bundles under normal operating conditions.

14/00820 Overview of design and thermal–hydraulic analysis of Indian solid breeder blanket concept

Chaudhuri, P. *et al. Fusion Engineering and Design*, 2013, 88, (4), 209–215.

India has developed two concepts of breeding blanket for the DEMO demonstration nuclear reactor: one is lead lithium ceramic breeder (LLCB), and the other one is helium-cooled ceramic breeder (HCCB) concept. The Indian HCCB concept is having the edge on the configuration of the helium-cooled solid breeder with a RAFMS structure. Li_2TiO_3/Li_4SiO_4 and beryllium are used as the tritium breeder and neutron multiplier, respectively. Two-dimensional thermal–hydraulic simulation studies using ANSYS have been performed based on the heat load obtained from neutronics calculations to confirm heat removal under International Thermonuclear Experimental Reactor (ITER) pulsed operations. Transient thermal analysis has been simulated in ANSYS for ITER-relevant operational conditions. Thermal analysis provides important information about the temperature distribution in different materials used and their temperature–time histories. Results of thermal–hydraulic simulations show that in each cycle the maximum temperature of all materials remains the same. The peak temperatures of all the materials are well within their limiting values. Concept designs of a HCCB blanket and its thermal hydraulic analysis are presented.

14/00821 Selection of sodium coolant for fast reactors in the US, France and Japan

Sakamoto, Y. *et al. Nuclear Engineering and Design*, 2013, 254, 194–217.

The joint paper presents a common view of fast reactor specific missions in the development of nuclear energy and a cross-analysis of merits and demerits of several fast reactors concepts studied worldwide and especially in the Generation-IV International Forum (GIF) framework. The paper provides the context for fast reactors development in the USA, France and Japan and focuses on the comparison on sodium-cooled fast reactors (SFRs), gas-cooled fast reactors (GFRs) and lead-cooled fast reactors (LFRs), i.e. the three fast reactor concepts that have the potential to meet the nuclear fuel cycle sustainability goals. The information provided in the article permits the reader to understand each country's objectives to see that not only the objectives searched for but also the technical orientations are converging. The authors underline that SFR technology evaluation relies significantly on the substantial base technology development programs within each country which is without comparison for the other two fast reactor technologies, e.g. SFR technology has already been developed to commercial or near commercial scale in each country whereas the performance of LFR and GFR technology is still uncertain. The main GFR merits are the potential for high temperatures and the easier possibilities for inspections and repairs. The main challenges are the fuel (fabrication, in-pile behaviour), materials for high temperatures, and the implementation of mitigation means to manage severe core degradation. The main LFR merit is the lack of chemical reactivity of the lead coolant with air and water. The main challenges are the development of corrosion resistant structural and cladding materials, the implementation of mitigation means to manage severe core degradation, the density of the lead, and the comparably large core size. The selection of a reference fast reactor concept in view of possible industrialization is made on a national base, taking into account the each countries' strategic objectives, existing technology base, the proven or expected technical performance, the R&D challenges and technical means to conduct that R&D, the possibility to share development costs and risks, etc. It is important to note that in different contexts, the USA, French, and Japanese organizations have selected the SFR as their reference fast reactor concept.

14/00822 Tritium breeding control within liquid metal blankets

Morgan, L. and Pasley, J. *Fusion Engineering and Design*, 2013, 88, (3), 107–112.

A key requirement for the DEMO demonstration nuclear power plant is the on-site breeding of tritium. In order to do this, a robust control system must be employed to ensure enough tritium is being bred to sustain the fusion reactor, while not breeding an amount which would exceed the plant's tritium inventory licence. A tritium breeding method which is cost-effective and reduces radioactive waste for disposal is that of the liquid metal breeder, such as those based around LiPB and FLiBe. This paper focuses on the modelling of a simplified fusion reactor design with a LiPb blanket with linked radiation transport, nuclide burn-up and control theory. Two simple models were simulated using the FATI code which incorporated a proportional integral derivative (PID) controller that adjusted the Li6/Li7 ratio in order to increase/decrease tritium production based on the difference between the measured excess tritium inventory and the desired excess inventory. The modelling has initially demonstrated that a linear PID controller has the capability to manage tritium production within a LiPb liquid blanket.

Economics, policy, supplies, forecasts

14/00823 A new design concept for offshore nuclear power plants with enhanced safety features

Lee, K. *et al. Nuclear Engineering and Design*, 2013, 254, 129–141.

This study presents a new concept for offshore nuclear power plants (ONPP) with enhanced safety features. The design concept of a nuclear power plant (NPP) mounted on gravity-based structures (GBSs), which are widely used offshore structures, is proposed first. To demonstrate the feasibility of the concept, a large-scale land-based nuclear power plant, model APR1400, which is the most recent NPP model in the Republic of Korea, is mounted on a GBS while minimizing modification to the original features of APR1400. A new total general arrangement and basic design principles are proposed and can be directly applied to any existing land-based large-scale NPPs. The proposed concept will enhance the safety of a NPP due to several aspects. A new emergency passive containment cooling system and emergency passive reactor-vessel cooling system are proposed; their features of using seawater as coolant and safety features against earthquakes, tsunamis, storms and marine collisions are also described. The authors believe that the proposed offshore NPP is more robust than conventional land-based NPPs and it has strong potential to provide great opportunities in nuclear power industries by decoupling the site of construction and that of installation.

14/00824 Accident like the Fukushima unlikely in a country with effective nuclear regulation: literature review and proposed guidelines

Wang, Q. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 126–146.

The reports from the International Atomic Energy Agency (IAEA) and the Japanese Nuclear and Industrial Safety Agency (NISA) have confirmed that the Fukushima Daiichi nuclear power plant (NPP) survived the initial earthquake impacts, but fell victim to the following tsunami. The 14-m tsunami well exceeded the maximum safety design of 5.7 m. It damaged the pumps, cut off the external power supplies to cool the reactors and spent fuel pool, and directly contributed to the three core meltdowns at the Fukushima Daiichi NPP. These official reports, academic papers, and breaking news also show that five warnings of tsunamis at the Fukushima Daiichi NPP had been ignored by the nuclear operator and regulators since 2000. This article argues that not the natural disaster, but the regulatory failures contributed to the worst nuclear accident since Chernobyl. It explains how the cozy relationship between the government, regulators and nuclear operators, the combined role of NISA as an industry promoter and regulator, and the revolving door between bureaucrats and industries had long undermined the capacity of NISA as a watchdog for nuclear safety. It concludes that upgrading and strengthening a nuclear regulatory system is not optional but imperative to prevent the next core meltdown. Three key recommendations are offered for upgrading nuclear safety regulation.

14/00825 Hot isostatically pressed wasteforms for future nuclear fuel cycles

Maddrell, E. *Chemical Engineering Research and Design*, 2013, 91, (4), 735–741.

Future nuclear fuel cycles will benefit from innovations in waste immobilization technology allowing optimized waste management strategies to be deployed. Hot isostatic pressing (HIP) has the potential to be central to these novel immobilization technologies because of its ability to consolidate a wide variety of wastes into durable waste forms. HIP is currently being developed by the National Nuclear Laboratory for the immobilization of plutonium-containing wastes and residues, but its flexibility as a process makes it ideal for future fuel cycles.

14/00826 Measures of the environmental footprint of the front end of the nuclear fuel cycle

Schneider, E. *et al. Energy Economics*, 2013, 40, 898–910.

Previous estimates of environmental impacts associated with the front end of the nuclear fuel cycle (FEFC) have focused primarily on energy consumption and CO_2 emissions. Results have varied widely. This work builds on reports from operating facilities and other primary data sources to build a database of front end environmental impacts. This work also addresses land transformation and water withdrawals associated with the processes of the FEFC. These processes include uranium extraction, conversion, enrichment, fuel fabrication, depleted uranium disposition, and transportation. To allow summing the impacts across processes, all impacts were normalized per tonne of natural uranium mined as well as per MWh(e) of electricity produced, a more conventional unit for measuring environmental impacts that facilitates comparison with other studies. This conversion was based on mass balances and process efficiencies associated with the current once-through light water reactor fuel cycle. Total energy input is calculated at 8.7×10^{-3} GJ(e)/MWh(e) of electricity and 5.9×10^{-3} GJ(t)/MWh(e) of thermal energy. It is dominated by the energy required for uranium extraction, conversion to fluoride compound for subsequent enrichment, and enrichment. An estimate of the carbon footprint is made from the direct energy consumption at 1.7 kg CO_2/MWh(e). Water use is likewise dominated by requirements of uranium extraction, totalling 154 L/MWh(e). Land use is calculated at 8×10^{-3} m^2/MWh(e), over 90% of which is due to uranium extraction. Quantified impacts are limited to those resulting from activities performed within the FEFC process facilities (i.e. within the plant gates). Energy embodied in material inputs such as process chemicals and fuel cladding is identified but not explicitly quantified in this study. Inclusion of indirect energy associated with embodied energy as well as construction and decommissioning of facilities could increase the FEFC energy intensity estimate by a factor of up to 2.

14/00827 Preliminary thermal-hydraulic and safety analysis of China DFLL-TBM system

Li, W. *et al. Fusion Engineering and Design*, 2013, 88, (5), 286–294.

China has proposed the dual-functional lithium-lead (DFLL) tritium breeding blanket concept for testing in the International Thermonuclear Experimental Reactor (ITER) as a test blanket module (TBM), to demonstrate the technologies of tritium self-sufficiency, high-grade heat extraction and efficient electricity production which are needed for the DEMO and fusion power plants. Safety assessment of the TBM and its auxiliary system should be conducted to deal with ITER safety issues directly caused by the TBM system failure during the design process. In this work, three potential initial events (PIEs) – in-vessel loss of helium (He) coolant and ex-vessel loss of He coolant and loss of flow without scram (LOFWS) – were analysed for the TBM system with a modified version of the RELAP5/MOD3 code containing liquid lithium-lead eutectic (LiPb). The code also comprised an empirical expression for MHD pressure drop relevant to three-dimensional effect, the Lubarsky–Kaufman convective heat transfer correlation for LiPb flow and the Gnielinski convective heat transfer correlation for He flow. Since both LiPb and He serve as TBM coolants, the LiPb and He ancillary cooling systems were modelled to investigate the thermal-hydraulic characteristic of the TBM system and its influence on ITER safety under those accident conditions. The TBM components and the coolants flow within the TBM were simulated with one-dimensional heat structures and their associated hydrodynamic components. ITER enclosures including vacuum vessel, port cell and TCWS vault were also covered in the model for accident analyses. Through this best estimate approach, the calculation indicated that the current design of DFLL-TBM and its auxiliary system meets the thermal-hydraulic and safety requirements from ITER.

14/00828 Reliability estimation of structures under stochastic loading – a case study on nuclear piping

Prasad, M. H. *et al. Nuclear Engineering and Design*, 2013, 254, 185–193.

Generally, structures are subjected to different types of loadings throughout their life time. These loads can be either discrete in nature or continuous in nature and also these can be either stationary or non-stationary processes. This means that the structural reliability analysis not only considers random variables but also considers random variables which are functions of time, referred to as stochastic processes. A stochastic process can be viewed as a family of random variables. When a structure is subjected to a random loading, based on the stresses developed in the structure and failure criteria the failure probability can be estimated. In practice the structures are designed with higher factor of safety to take care of such random loads. In such cases the structure will fail only when the random loads are cyclic in nature. In traditional reliability analysis, the variation in the load is treated as a random variable and to account for the number of occurrences of the loading the concept of extreme value theory is used. But with this method one is neglecting the damage accumulation that will take place from one loading to another loading. Hence, in this paper, a new way of dealing with these types of problems has been discussed by using the concept of stochastic fatigue loading. The random loading has been considered as earthquake loading. The methodology has been demonstrated with a case study on nuclear power plant piping.

14/00829 Safety design of next generation SUI of CANDU stations

Nasimi, E. and Gabbar, H. A. *Nuclear Engineering and Design*, 2013, 254, 53–66.

Due to the age and operating experience of nuclear power plants, equipment ageing and obsolescence has become one of the main challenges that need to be resolved for all systems, structures and components in order to ensure a safe and reliable production of energy. This paper summarizes the research into a methodology for modernization of start-up instrumentation (SUI), both in-core and control room equipment, using a new generation of detectors and cables in order to manage obsolescence. The main objective of this research is to develop a new systematic approach to SUI installation/replacement procedure development and optimization. Although some additional features, such as real-time data monitoring and storage/archiving solutions for SUI systems are also examined to take full advantage of today's digital technology, the objectives of this study do not include detailed parametrical studies of detector or system performance. Instead, a number of technological, operational and maintenance issues associated with start-up instrumentation systems at nuclear power plants will be identified and a structured approach for developing a replacement/installation procedure that can be standardized and used across all of the domestic CANDU (Canadian deuterium–uranium) stations is proposed.

14/00830 The application of contrast explanation to energy policy research: UK nuclear energy policy 2002–2012

Heffron, R. J. *Energy Policy*, 2013, 55, 602–616.

This paper advances the application of the methodology, contrast explanation, to energy policy research. Research in energy policy is complex and often involves inter-disciplinary work, which traditional economic methodologies fail to capture. Consequently, the more encompassing methodology of contrast explanation is assessed and its use in other social science disciplines explored in brief. It is then applied to an energy policy research topic – in this case, nuclear energy policy research in the UK. Contrast explanation facilitates research into policy and decision-making processes in energy studies and offers an alternative to the traditional economic methods used in energy research. Further, contrast explanation is extended by the addition of contested and uncontested hypotheses analyses. This research focuses on the methods employed to deliver the new nuclear programme of the UK government. In order to achieve a sustainable nuclear energy policy three issues are of major importance: (1) law, policy and development; (2) public administration; and (3) project management. Further, the research identifies that policy in the area remains to be resolved, in particular at an institutional and legal level. However, contrary to the literature, in some areas, the research identifies a change of course as the UK concentrates on delivering a long-term policy for the nuclear energy sector and the overall energy sector.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

14/00831 A comprehensive review on the grid integration of doubly fed induction generator

Jadhav, H. T. and Roy, R. *International Journal of Electric Power & Energy Systems*, 2013, 49, 8–18.

As a result of the growing demand for electricity and environmental constraints, the generation of electrical energy from renewable sources of energy has recently increased. The renewable energy sources, especially wind power plants are integrated to power networks all around the world. The rising share of wind turbine energy, in the existing power system, has created new opportunities and challenges. For wind turbine energy generation, doubly-fed induction generators (DFIG) are most suitable due to their various advantages over fixed speed wind turbine systems. These generators have ability to improve stability and power quality of the existing power systems. Therefore more attention has been paid by many researchers recently to address various challenges of grid connection of DFIG. A comprehensive survey, of different issues associated with integration of DFIG-based system into the grid is presented in this paper. The survey revealed that researchers have extensively employed the potential of power electronics and advanced control theories to optimize the performance of DFIG-based power systems. It was also found that the potential of nature-inspired optimization algorithms is not fully exploited for power system optimum performance. The share of DFIG-based wind turbines is increasing in the market due to its low cost and the small-size power electronics system. As a result of growth in power electronic technology, the use of variable-speed wind turbines with a full-scale power converters may be an alternative to DFIG. Furthermore, the use of flexible AC transmission devices to further support the grid performance can be another alternative for better power generation and control systems.

14/00832 A mixed-integer LP model for the optimal allocation of voltage regulators and capacitors in radial distribution systems

Franco, J. F. *et al. International Journal of Electric Power & Energy Systems*, 2013, 48, 123–130.

This paper presents a mixed-integer linear programming model (LP) to solve the problem of allocating voltage regulators and fixed or switched capacitors (VRCs) in radial distribution systems. The use of a mixed-integer linear model guarantees convergence to optimality using existing optimization software. In the proposed model, the steady-state operation of the radial distribution system is modelled through linear expressions. The results of one test system and one real distribution system are presented in order to show the accuracy as well as the efficiency of the proposed solution technique. An heuristic to obtain the Pareto front for the multiobjective VRCs allocation problem is also presented.

14/00833 A new multi-objective for environmental and economic management of Volt/Var control considering renewable energy resources

Zare, M. and Niknam, T. *Energy*, 2013, 55, 236–252.

The environmental and economic aspects of the Volt/Var control problem as well as technical issues of the networks, transform the classical problem into multiobjective one. In this paper, a multi-objective θ-smart bacterial foraging algorithm (Mθ-SBFA) is proposed to solve the Volt/Var control problem in distribution networks including renewable energy sources (RESs) involving the conflicting objectives, i.e. the electrical energy losses, the voltages deviations, the total electrical energy costs and the total emissions of RESs and substations. The proposed algorithm goes through the search space in the polar coordinates instead of the Cartesian one; whereby the feasible space is more compact. Also, several modifications are applied to restraint the premature convergence of the solutions. Hence, the bacteria in chemotaxis process are moved in short or long steps as well as swimming movement. Furthermore, replacement the least healthy bacteria are done by the strong dominated solutions reserved along the iterative search process. A new approach based on the variance of the objective functions is utilized to select the population; thereby lead to uniformly distributed the pareto-optimal front (POF) as well as reach to extreme points of the solutions. Niching mechanism, besides the smart population, leads the bacteria towards the lesser covered space of the POF. A fuzzy clustering technique controls the size of the repository when it gets filled. Finally, two test distribution feeders are used to assess the performance of the proposed modifications.

14/00834 A resorption cycle for the cogeneration of electricity and refrigeration

Wang, L. *et al. Applied Energy*, 2013, 106, 56–64.

This paper describes a novel resorption cycle driven by the low-grade heat for the cogeneration of electricity and refrigeration, which is based on ammonia adsorption refrigeration technology. The presented cycle features a variable endothermic process which stands for higher adaptability if compared with the traditional Rankine cycle, very little or no ammonia liquid in the system which is a safety feature, solid adsorbents inside the beds, and simple structure for the fact of no rectifying equipment and circulation pumps required by the working fluids. This cycle can be utilized for the heat source with the temperature higher than 100 °C, and it has an electricity generation exergy efficiency of up to 0.69 and a refrigeration coefficient of performance (COP) of up to 0.77. If compared with the Goswami cycle, which is established based on the absorption Kalina cycle for the cogeneration of electricity and refrigeration, the novel resorption cycle kept the merit of the high exergy efficiency for electricity generation, meanwhile, it overcame the limitation of the low refrigeration COP of Goswami cycle, and improved the COP by 10 times. The optimum overall exergy efficiency is as high as 0.9, which is 40–60% improved compared with the Goswami cycle under the same working conditions.

14/00835 A review of energy storage systems in microgrids with wind turbines

Rabiee, A. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 316–326.

Installing energy storage systems (ESS) for wind turbines power can bring many benefits to both power grids and wind power developers. Considering stochastic nature of wind, electric power generated by wind turbines is highly erratic and may affect both the power quality and the planning of power systems. ESS should play a key role in wind power applications by controlling wind power plants output and providing ancillary services to the power system, and therefore, enabling an increased penetration of wind power in the system. This paper reviews various storage systems for wind power applications and points out that the operation of power systems through wind power plants can have several benefits. High-power ramp rates of some systems such as superconducting magnetic energy storage, flywheels or super-capacitors allow their use for power smoothing of wind turbines, favouring the mitigation of the voltage and frequency variations at the connection point of the wind power plant. Regarding the use of short time-scale storage technologies, their optimal location in the wind plant and sizing have to be addressed in order to ensure their proper operation. In addition, since the current source power converters of the ESS have to interact with the power converters of wind turbines in most of the cases, the topology of the wind plant, as well as the wind turbine types and control strategies play a key role in the system operation and design. Other aspects related with the system stability under perturbations, like oscillation damping issues and low-voltage ride-through capability, become clearly improved with energy storage support. These capabilities take on a key role from their incorporation into grid codes. Once more, energy technologies with high ramp rates are required. The technical feasibility of isolated and hybrid systems with high penetration rates of wind power become significantly improved, since the predictability of wind power plants with ESS is increased. Also, a continuous power supply for the loads of such systems can be ensured. The predictability improvement of the output of wind power plants with an ESS not only involves technical benefits that favour the incorporation of wind power in the network, but also economic benefits owing to the penalty reductions in forecasting errors. In addition, operation costs of the power system can be reduced due to the reduced power reserve requirements of the system. The installation of ESS strongly depends on the economic viability of the project. In this sense, although hydrogen-based storage technologies have a great potential for long-term storage applications, the main challenges for their inclusion are related to the uncertainty of their economic viability (due to high system costs and low energy efficiency) and the dependence on high hydrogen market prices. A proper control strategy by the system operator is necessary in order to ensure the correctness in the utilization of long term storage systems. In addition, it is found that ESS operators should receive subsidies according to the emissions that would imply the use of conventional fuel plants for peak shaving applications, in order to make their use economically profitable. Nowadays, there is a tremendous effort in improving the capabilities and efficiencies of the available storage systems, as well as reducing their capital costs. The aim of this research is to make ESS economically suitable for the use in stationary applications and, therefore, allow higher penetration ratios of renewable energies in the power system.

14/00836 An active islanding detection technique for current controlled inverter

Rani, B. I. *et al. Renewable Energy*, 2013, 51, 189–196.

This paper presents an active islanding detection technique suitable for current controlled inverters. The method is based on reducing the magnitude of the injected current periodically and monitoring the voltage at the point of common coupling (PCC). Under grid failure, the change in voltage at the PCC exceeds the allowable voltage threshold and islanding is detected. The change in the PCC voltage depends on the ratio by which current is reduced and is independent of the magnitude of current. Hence the voltage threshold remains the same irrespective of the loading conditions. A simple control circuit is incorporated into the inverter control to enable islanding detection. The perturbation caused by this method does not affect the zero crossing of the inverter current nor introduce any distortion as in case of other active anti islanding techniques. The performance of the proposed technique applied to a current controlled inverter is simulated in MATLAB/Simulink environment. The feasibility of the technique is ascertained by conducting experimental test on the prototype unit built in the laboratory. The algorithm is implemented on an ALTERA CYCLONE II FPGA board and the results are presented to show that the proposed method can effectively detect the islanding condition regardless of the load conditions.

14/00837 Application of hybrid micro-cogeneration system – thermal and power energy solutions for Canadian residences

Entchev, E. *et al. Energy and Buildings*, 2013, 60, 345–354.

This paper presents results from a field trial with a hybrid micro-cogeneration system applied to satisfy both thermal and power needs of a typical Canadian detached house. The hybrid system consists of an internal combustion engine integrated with a high efficiency furnace. It was installed, integrated with the rest of the mechanical systems and demonstrated at the Canadian Center for Housing Technology. Cost analysis was performed to examine the economics of such systems in relation to different price structures imposed by the electric utilities. The study revealed that the hybrid micro-cogeneration system performed reliably and generated both heat and power with high efficiency during the heating season and was able to satisfy the heating demand under very cold weather conditions. The power generated by the system was first directed to the house satisfying 50% of the electric load with the other 50% being exported to the grid. The project demonstrated that micro-cogeneration systems when sized to meet the base electric load and design thermal load of the residence are a valuable alternative to the central power generation plants and are able to reliably satisfy the house thermal/power demand even under extreme cold conditions.

14/00838 Control of parallel-connected ac to dc converter with droop technique for dc microgrid application

Tarasantisuk, C. *et al. Energy Procedia*, 2013, 34, 351–361.

This paper presents the control of a single-phase ac to dc converter using the rotating reference frame control methodology wherein the phase angle obtained from a single-phase phase-locked loop is used for axis-transformation. The I_d, I_q currents and output voltage of the converter are then controlled by PI control strategy. The dc microgrid under study consists of two modules of the ac to dc converters connected in parallel topology using droop control technique. The simulation results based on Matlab/Simulink illustrate that I_d,I_q currents can be regulated by the designed PI controllers. Therefore, zero steady-state error and simple power calculation are achieved. Also, real power sharing between the two converters is fulfilled by the parallel-connected converter topology with droop controller in such a dc microgrid system, while the output voltage is maintained at 600 V by a PI controller at the secondary control level.

14/00839 Effects of supplementary biomass firing on the performance of combined cycle power generation: a comparison between NGCC and IGCC plants

Bhattacharya, A. and Datta, A. *Biomass and Bioenergy*, 2013, 54, 239–249.

In this study, effects of biomass supplementary firing on the performance of fossil fuel fired combined cycles have been analysed. Both natural gas-fired combined cycle (NGCC) and integrated coal gasification combined cycle (IGCC) have been considered in the study. The efficiency of the NGCC plant monotonically reduces with the increase in supplementary firing, while for the IGCC plant the maximum plant efficiency occurs at an optimum degree of supplementary firing. This difference in the nature of variation of the efficiency of two plants under the influence of supplementary firing has been critically analysed in the paper. The ratings of different plant equipments, fuel flow rates and the emission indices of CO_2 from the plants at varying degree of supplementary firing have been evaluated for a net power output of 200 MW. The fraction of total power generated by the bottoming cycle increases with the increase in supplementary firing. However, the decrease in the ratings of gas turbines is much more than the increase in that of the steam turbines due to the low work ratio of the topping cycle. The NGCC plants require less biomass compared to the IGCC under identical condition. A critical degree of supplementary firing has been identified for the slag free operation of the biomass combustor. The performance parameters, equipment ratings and fuel flow rates for no supplementary firing and for the critical degree of supplementary biomass firing have been compared for the NGCC and IGCC plants.

14/00840 General aspects, hierarchical controls and droop methods in microgrids: a review

Planas, E. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 147–159.

Distributed generation is emerging as a new technology for supplying the increasing demand for electricity. Microgrids are attracting a great deal of attention since they integrate distributed generation in the main grid reliably and cleanly. When designing the control system of a microgrid, several functions must be considered, such as the management of electrical and thermal energy, load management, synchronization with the main grid, etc. Both companies and institutions have carried out research into the control of microgrids over recent years and many proposals can be found in the literature. Thus, the design of the control system of a microgrid is a complex task due to its multiple functions and the large number of proposed solutions. This paper presents a complete description of the main features of a microgrid and describes the characteristics of the control systems used. Details are provided of the control tasks involved and of the main types of controls proposed in the literature. In addition, this paper describes the controls used in existing microgrids all over the world and proposes future areas for research.

14/00841 Low voltage model for the study of slow disturbances in medium voltage grids

Blanes, J. *Electric Power Systems Research*, 2013, 99, 64–70.

This paper presents a technique to obtain a model of the low voltage (LV) loads for proper reproducibility of the current during a slow voltage disturbance. For the synthesis of the load model, the LV currents and voltages recorded during a voltage dip generated in the high voltage system have been used. Then, the model will be valid as long as the loads remain substantially constant. This process should be repeated for different load 'scenarios', i.e. for the three or four main stages of the production process in which the activity of the plant can be structured, in order to have a model valid for each of these stages. Following this line of future works, the model has been proposed for a situation where the induction motors are the most important dynamic loads. Although this is the most usual situation, the model should be further examined to include the cases in which synchronous or DC motors are relatively important. Even in the realm of induction motors, these have been considered directly by electronic speed drives, hence it would be very interesting to analyse their influence on this model.

14/00842 Model based evaluation of six energy integration schemes applied to a small-scale gasification process for power generation

Palma, C. F. and Martin, A. D. *Biomass and Bioenergy*, 2013, 54, 201–210.

This work considers the use of spent poultry litter as a fuel for on-site power generation. On-site use eliminates the need for the transportation of biomass to centralized plants and the associated bio-security issues. This work utilized process simulation to investigate six process integration schemes applied to a small scale gasification unit with a gas turbine prime mover. The model was used to evaluate schemes involving atmospheric gasification, pressurized gasification and recuperation of energy from the gas turbine exhaust gases. The recuperation of residual heat to preheat air and produced gases was performed with the aim of achieving the highest electrical efficiency. The cold gasification and exergy efficiencies were in the ranges of 58.4–79.5% and 46.8–65.7%, respectively, which mainly increased with increasing equivalence ratio and then after achieving the maximum value declined. The preferred configuration of the proposed 200-kW process achieved electrical efficiencies between 26% and 33.5%.

14/00843 Optimal design and operation of distributed energy systems: application to Greek residential sector

Mehleri, E. D. *et al. Renewable Energy*, 2013, 51, 331–342.

This work presents an optimization based approach for the integrated plan and evaluation of distributed energy resources (DER) systems. The mathematical model takes into account site energy loads, local climate data, utility tariff structure, characteristics of the candidate DER technologies (technical and financial) as well as geographical aspects. The optimal integrated DER system is selected by minimizing the total energy cost while guaranteeing reliable system operation. As an illustrative example, the authors consider a neighbourhood in Athens, Greece, where several options for satisfying its electricity and heat demands are investigated. The adoption of DER technologies combined with a heating pipeline network and a microgrid is examined.

14/00844 Optimal penetration levels for inverter-based distributed generation considering harmonic limits

Pandi, V. R. *et al. Electric Power Systems Research*, 2013, 97, 68–75.

The installation of inverter-based distributed generation (DG) has been increasing rapidly in recent years, and specifically, photovoltaic power systems. Such increased penetration will result in increased harmonics which could exceed the IEEE 519 allowable harmonic distortion levels. In this paper, the maximum DG penetration level is determined taking into consideration the IEEE 519 allowable voltage harmonic limits. The proposed study is formulated as a mixed integer non-linear programming problem where harmonics are determined using the decoupled harmonic power flow approach. The maximum DG penetration level based on optimal DG size and location is determined using particle swarm optimization algorithm. The proposed formulation is tested on 18-bus and 33-bus radial distribution systems considering 10 load and DG scenarios. The results show that by decentralizing the DG capacity, higher penetration levels could be achieved. The limiting effect of preinstalled DG at a certain bus on the overall DG penetration is also analysed.

14/00845 Optimization of a hybrid diesel-wind generation plant with operational options

Hu, Y. and Solana, P. *Renewable Energy*, 2013, 51, 364–372.

Hybrid diesel–wind power generation systems have a great potential in the application of providing energy supply for remote communities and facilities. Compared to the traditional diesel system, hybrid power plants can offer many advantages such as additional capacity, being more environmentally friendly, potential reduction of cost, etc. One of the problems for the hybrid system is the uncertain profit due to the uncertain nature of the wind. In this paper a general model is presented based on real option theory for valuating a hybrid diesel–wind generation plant. A dynamic programming method is used to generate the optimum operational option by maximizing the net cash flow of the plant. Results show that operational options can provide additional value to the hybrid power system when this operational flexibility is correctly utilized. The optimal scale of wind turbines generators can be calculated as a consequence of the limitation of demand and local wind power density. This paper also provides a framework to find the optimal operating decision at each time step based on the real option model.

14/00846 Overvoltage prevention in LV smart grid using customer resources coordination

Mokhtari, G. *et al. Energy and Buildings*, 2013, 61, 387–395.

Voltage rise is one of the main factors which limits the capacity of low voltage (LV) network to accommodate more renewable energy (RE) sources. This paper proposes a robust and effective approach to coordinate customers' resources and manage voltage rise in residential LV networks. PV is considered as the customer RE source. The suggested coordination approach in this paper includes both localized control strategy, based on local measurement, and distributed control strategy based on consensus algorithm. This approach can completely avoid maximum permissible voltage limit violation. A typical residential LV network is used as the case study where the simulated results are shown to verify the effectiveness of the proposed approach.

14/00847 Process integration of hybrid power systems with energy losses considerations

Rozali, N. E. M. *et al. Energy*, 2013, 55, 38–45.

The application of process integration using the pinch analysis technique has been recently extended to the design of hybrid power systems to determine the maximum power recovery and the battery storage capacity. The graphical and the numerical power pinch analysis (PoPA) tools provide designers with visualization tools that are systematic and simple to implement for the optimization of power systems. However, the power losses incurred in the systems, have so far, not been considered in detail in the previous works. This paper extends the PoPA method by considering the power losses that occur during the power system's conversion, transfer and storage. The effects of the losses on the minimum outsourced electricity targets and the storage capacity are evaluated. The storage cascade table of PoPA has been further developed to include the effect of energy losses in the system's design. Application of the developed method on a case study yields the more realistic power targets for off-grid hybrid power systems.

14/00848 Review of transmission schemes and case studies for renewable power integration into the remote grid

Hasan, K. N. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 568–582.

Investment in transmission for renewable power penetration to the remote grid essentially faces a set of inherent, regulatory, economic and technical challenges. This work investigates these challenges to enhance renewable power integration into the remote grid. This study aims to enhance regulatory policies and associated planning frameworks to be more efficient and justifiable for renewable power integration paradigm. First, a set of leading transmission schemes practised, or investigated, in different countries are evaluated against the challenges which are obvious for long distance renewable power transmission. Second, a net benefit framework is presented to address the challenging issues of location constrained renewable power penetration into the Queensland network of the Australian grid. The proposed framework incorporates the carbon emission price as an environmental benefit which significantly influences the cost–benefit analysis. This paper discusses the 'hub approach' of network integration. The transmission investment cost allocation is addressed here as well. The concepts are verified through the implementation of the proposed framework in four prospective projects of the Queensland network in the Australian national electricity market.

14/00849 Simultaneous anaerobic sulfide and nitrate removal coupled with electricity generation in microbial fuel cell

Cai, J. *et al. Bioresource Technology*, 2013, 129, 224–228.

Two-chamber microbial fuel cells (MFC) using graphite rods as electrodes were operated for simultaneous anaerobic sulfide and nitrate removal coupled with electricity generation. The MFC showed good ability to remove substrates. When the influent sulfide and nitrate concentrations were 780 and 135.49 mg/L, respectively, the removal percentages of sulfide and nitrate were higher than 90% and the main end products were nitrogen and sulfate. The MFC also showed good ability to generate electricity, and the voltage went up with the rise of influent substrate concentrations. When the external resistance was $1000\,\Omega$, its highest steady voltage was 71 mV. Based on the linear relationship between the electrons released by substrates and accepted by electrode, it was concluded that the electricity generation was coupled with the substrate conversion in the MFC.

14/00850 Solving the economic dispatch problem by using Tabu search algorithm

Naama, B. *et al. Energy Procedia*, 2013, 36, 694–701.

This paper presents an algorithm for solving security constrained economic dispatch (SCED) problem through the application of Tabu search (TS). The SCED problem is formulated with base case and contingency case line flow constraints, which are important for practical implementation. One representative system, namely a IEEE 57-bus system, is used for the investigations. The SCED results obtained using TS are compared with those obtained using a genetic algorithm, a quasi-Newtonian method and Mat-Power.

14/00851 Study of optimal design of polygeneration systems in optimal control strategies

Menon, R. P. *et al. Energy*, 2013, 55, 134–141.

The concept of smart grids being developed involves interdependence between the electrical, thermal and material flows. Control strategies are required for the optimal operation of these modern grids. This paper studies the optimal design of multi-node microgrids integrating heat pumps and cogeneration units considering optimal predictive control strategies. A few case studies have been implemented to demonstrate the interest of the optimal design strategies at various levels of the modern grids: at local level, multiple building level and at the grid level. This has been further elaborated by studying the influence of electrical pricing and electrical grid constraints.

14/00852 Supercapacitive performance of nitrogen-enriched carbons from carbonization of polyaniline/activated mesocarbon microbeads

Wu, C. *et al. Journal of Power Sources*, 2013, 227, 1–7.

With the direct carbonization using polyaniline/activated mesocarbon microbead (PANI/ACMB) composites as the precursor and subsequent activation treatment with 16 M HNO_3, the activated nitrogen-enriched novel carbons (a-NENCs) can be prepared. Scanning electron microscopy, Fourier infrared spectroscopy, X-ray photoelectron spectroscopy (XPS) and nitrogen adsorption/desorption isotherm at 77 K are utilized to characterize the structure, morphology and physicochemical properties of the a-NENCs. The result shows that the a-NENCs keep the original leechee-like morphology of the PANI/ACMB composites. The supercapacitive performances of the a-NENCs are investigated with cyclic voltammetry, galvanostatic charge/discharge tests, impedance spectroscopy and cycle life measurements in 6 M KOH. The results based on galvanostatic charge/discharge tests demonstrate that the maximum specific capacitance of the a-NENCs electrode is $385\,\mathrm{F\,g^{-1}}$. Meanwhile, the specific capacitance of the button supercapacitor using a-NENCs as electrode active material is as high as $89.5\,\mathrm{F\,g^{-1}}$ at the charge/discharge current density of $500\,\mathrm{mA\,g^{-1}}$. These remarkable results demonstrate the exciting commercial potential for high performance, environmentally friendly and low-cost electrical energy-storage devices based on this new material.

14/00853 Technical evaluation of a power generation process consuming municipal solid waste

de Souza-Santos, M. L. and Ceribeli, K. *Fuel*, 2013, 108, 578–585.

The technical feasibility study of a thermoelectric power generation process consuming municipal solid waste is presented. Such fuel is fed into a bubbling fluidized bed boiler with combustion chamber pressurized at 4 MPa. The flue gas is cleaned and injected into gas turbines while the produced steam at 10 MPa is diverted to a Rankine cycle. Costly and cumbersome cascade feeding systems are avoided by feeding the particulate MSW as slurry into the pressurized combustion chamber. Therefore, the present process dispenses fuel drying – as usually required by more conventional processes – leading to substantial savings on capital and operational costs. Additionally, the characteristics of bubbling fluidized bed combustors allows for low pollutant emissions, which should also decrease the costs of further cleaning in order to comply with required for emissions to environment. A comprehensive simulator is applied to predict the boiler operational behaviour, while another is employed to simulate the power unit. The work shows the possibility of achieving power-generation efficiencies above the usually found for such a low-grade fuel. Therefore, the present process is believed to be a good alternative for discharging of waste while supplementing power for medium to large cities. The present work does not include considerations on economics of the proposed process; however provides information for future studies on such aspects.

14/00854 Temperature profile of progressive damaged overhead electrical conductors

Cimini Jr, C. A. *et al. International Journal of Electric Power & Energy Systems*, 2013, 49, 280–286.

The Brazilian transmission system is characterized by installations that average 20 years of operation. Competitiveness of the energy sector, lack of resources for new investments and the aging of the system lead to the necessity of not only to reform but also to optimize it in order to face the increasing demand of the Brazilian energy market. The overhead electrical conductor is naturally the most important element on the transport of electrical energy and requires careful predictive and preventive maintenance programs. Therefore, it is of fundamental importance to predict the operational life of overhead electrical conductors using mathematical models so that their energy transport capacity can be optimized. However, it is necessary to validate such models by means of test programs so that their predictions can be trusted. One of the most important factors on the structural decay of overhead electrical conductors is the variation of the temperature profile in the event of the rupture of one or more of its aluminium wires by fatigue or fretting. Therefore, models that include this temperature variation must be validated through test programs that can experimentally establish a mathematical relationship which considers effects such as contact resistance, material thermo-mechanical properties modification, annealing of the material and the presence of defects. The objective of this work is to evaluate the effect of progressive aluminium wire rupture on the temperature profile of an aluminium conductor steel reinforced overhead electrical conductor, not only on the section of the damage but also along the length of the conductor. A test procedure was developed and performed to establish this effect. Results were compared to a mathematical model and showed that the temperature profile dependency of the increasing rupture of aluminium wires is not linear and includes effects other than the cross-section loss.

14/00855 The load characteristics classification and synthesis of substations in large area power grid

Wang, Z. *et al. International Journal of Electric Power & Energy Systems*, 2013, 48, 71–82.

It is very difficult to build load model for every substation since there are numerous substations in large area power grid. A practical method is to classify the substations into several classes, pick out a typical substation from each class and build its load model, then generalize it to other substations of the same class. In this paper, a new method based on self-organization map (SOM) neural network is presented for load characteristics classification and synthesis of substations in large area power grid. SOM neural network is a clustering method with self-organizing characteristics and mapping capability that can classify different input patterns automatically. Besides, the trained SOM neural network can discriminate the new input pattern conveniently without retraining. Therefore, the new substations can be discriminated with the existing classification result unchanged. The effectiveness of the proposed method is verified by a simulation of 183 220 kV substations in Shandong power grid using MATLAB Neural Network Toolbox. At first, the load composition rate in each substation is chosen as the feature vector, then the SOM neural network is introduced to the classification and synthesis of the load characteristics of substations. At last, the synthetic load characteristic of each class is derived from the cluster centre. The result is satisfactory since the method not only decreases the randomness and subjectivity of the load characteristic classification and synthesis of substations, but also improves the effectiveness and efficiency of load modelling. The method offers a new way for practical load modelling.

Economics, policy, supplies, forecasts

14/00856 3-Phase 4-leg unified series–parallel active filter system with ultracapacitor energy storage for unbalanced voltage sag mitigation

Ucar, M. and Ozdemir, S. *International Journal of Electric Power & Energy Systems*, 2013, 49, 149–159.

This paper presents the analysis and design of a three-phase four-leg (3P4L) unified series–parallel active filter (USPAF) with ultracapacitor energy storage (UCES) for improving the power quality in three-phase four-wire (3P4W) distribution system. The series and parallel active filter (AF) of 3P4L USPAF system are realized by four-leg voltage source inverters (VSIs) to a common dc-link capacitor. Due to its high power density, the UCES is well suited to supply high power for short period of time. The objective of this paper is to enhance the unbalanced voltage sag mitigating capability of the 3P4L USPAF system by adding UCES, directly connected in the dc-link. This is achieved by injecting energy from the UCES to maintain the dc-link voltage constant. Thus, the proposed system is capable of mitigating unbalanced voltage sag with zero-sequence component in the source voltage and compensating harmonic, reactive power and unbalanced current of the load in 3P4W distribution systems. The proposed scheme is validated by an experimental prototype with a 1.93 F UCES bank and using dSPACE DS1103 real-time control platform in the laboratory. The experimental results show that the combined system offer improved performance to maintain the load voltage constant at its rated value during unbalanced voltage sag in the supply voltage.

14/00857 A long term generation expansion planning model using system dynamics – case study using data from the Portuguese/Spanish generation system

Pereira, A. J. C. and Saraiva, J. T. *Electric Power Systems Research*, 2013, 97, 41–50.

This paper describes a long-term generation expansion model that uses system dynamics to capture the interrelations between different variables and parameters. Using this model, it is possible to estimate the long-term evolution of the demand and of the electricity price that are then used by generation agents to prepare individual expansion plans. These plans are submitted to a coordination analysis to check some global indicators, as the reserve margin and the loss-of-load expectation. The developed approach is illustrated using a realistic generation system based on the Portuguese/Spanish system with an installed capacity of nearly 120 GW and an yearly demand of 312 TWh in 2010. Large investments were directed in the last 20 years to the Iberian generation system both regarding traditional technologies and dispersed generation (namely wind parks and solar systems). Today, the excess of installed capacity together with the demand reduction poses a number of questions that should be addressed carefully namely to investigate the impact of several options. The planning exercise aims at identifying the most adequate expansion plans in view of the increased renewable generation (namely wind parks). For illustration purposes, the authors also conducted a sensitivity analysis to evaluate the impact of increasing the installed capacity in wind parks, of internalizing CO_2 emission costs and of incorporating a capacity payment. These analyses are relevant in order to get more insight on the possible long-term evolution of the system and to allow generation companies to take more sounded decisions.

14/00858 A multiple strategic evaluation for fault detection in electrical power system

Singh, A. K. and Parida, S. K. *International Journal of Electric Power & Energy Systems*, 2013, 48, 21–30.

A new combined formalism is described to detect faults in electrical power systems in this work. The aim of fault detection is to monitor and control the system which guarantees stable supply of electrical energy to consumers. To solve this problem, it has been proposed an integrated use between state space, optimization and analytical method by establishing a methodology for its completion. Initially, state space method performs through deviations signalled by its output, an analysis with relation to direction of fault in each component of power system. Though, state space is in possession of as much information as possible coming from output signals, can identify direction where disturbance has been occurred. Finally, the processing is done by optimization and analytical methods, which analyse the exact fault type and locations, using these signs, corrective action have been taken. By using proposed technique, the tasks of fault detection, classification, and location are accomplished. The common case of faults occurring in the electrical power system has been illustrated to verify the proposed methodology.

14/00859 A new approach to congestion pricing in electricity markets: improving user pays pricing incentives

Nelson, T. and Orton, F. *Energy Economics*, 2013, 40, 1–7.

Electricity pricing has traditionally been based on average cost pricing where consumers pay a 'flat' tariff based upon the average cost of production and transportation of electricity. The introduction of new 'smart' meters allows electricity providers to differentiate tariffs on the basis of time. Utilizing congestion pricing theory, the energy industry has embraced 'time-of-use' (ToU) tariffs with a view to more efficiently pricing electricity. This paper demonstrates that pricing as a function of demand variability (reflecting capacity utilization) is a more appropriate alternative to existing ToU tariffs for more efficiently allocating costs to end users. The authors call this new alternative pricing model 'first derivative ratio' pricing. This new approach to congestion pricing could be applied to markets other than electricity, such as road transportation.

14/00860 An optimal pricing scheme in electricity markets by parallelizing security constrained optimal power flow based market-clearing model

Kim, M. K. and Hur, D. *International Journal of Electric Power & Energy Systems*, 2013, 48, 161–171.

To improve economic efficiency of electricity markets, the market-clearing model must be designed to give transparent information for pricing system security and to quantify the correlation between the market operations and the power systems operations, which is an immensely provocative and challenging issue in electricity markets. This paper sets out to propose a novel approach to pricing the system security by parallelizing the security constrained optimal power flow (SCOPF) based market-clearing model, while providing market solutions as a function of complying with the required voltage security margin and $N-1$ contingency criteria. The proposed SCOPF based market-clearing framework also takes into consideration the bilateral transaction information and, at the same time, optimal pricing expressions through computing locational marginal prices and nodal congestion prices for ensuring voltage security are derived. The results from a 129-bus model of the Italian high-voltage transmission system turn out to be the validity of the proposed market-clearing model for managing and pricing the system security.

14/00861 Comparative energy and exergy performance assessments of a microcogenerator unit in different electricity mix scenarios

Gonçalves, P. *et al. Energy Conversion and Management*, 2013, 73, 195–206.

The European Union Directive 2004/8/EC on the promotion of cogeneration proposes a comparative indicator based on primary energy savings, neglecting some important thermodynamic aspects, such as exergy. This study aims to compare and discuss the usefulness of a set of complementary indicators for performance assessments of cogeneration systems, concerning thermodynamic principles based on first and second law (the exergy approach). As case study, a 6 kW electric output micro-combined heat and power unit was experimentally tested and a model of the unit was developed in TRNSYS. Considering as reference a set of different heat and electricity scenarios, including the actual electric mixes of Portugal and Italy, the indicators primary fossil energy savings and primary and total irreversibilities savings (PIS and TIS), as well as energy and exergy renewability ratios were assessed and discussed. The results show that the use of micro-combined heat and power has higher advantages for the Italian electric grid, than an equivalent scenario considering the Portuguese electric network as reference. As result, for a particular scenario analysed, PES and PIS have 3% and 6% for Portugal, and 10% and 18% for Italy, respectively. Furthermore, for one particular scenario evaluated, the indicators energetic and exergetic renewability ratios have 23% and 14%, respectively for the Portuguese electric grid, and 19% and 10% for the Italian electric system.

14/00862 Comparing solar PV (photovoltaic) with coal-fired electricity production in the centralized network of South Africa

de Groot, R. A. F. *et al. Energy*, 2013, 55, 823–837.

South Africa has a highly centralized network, in which almost all electricity is produced in Mpumalanga and transmitted throughout South Africa. In the case of the Western Cape, electricity has to be transmitted over 800–1370 km. This generates losses and entails high transmission costs. Investments in additional production and transmission capacity are needed to cope with the growing demand. Although there is a large potential for solar energy in South Africa, investments are lacking while large investments in new coal-fired power plants are being executed. These coal power plants do not only increase the need for heavier transmission infrastructure, but also have a higher CO_2 emission level and a higher pressure on water reserves. This paper performs a more comprehensive cost-analysis between solar energy production and coal production facilities, to make a more elaborate picture of which technologies are more plausible to foresee in the growing demand of electricity. The current centralized electricity infrastructure makes the investment in large production facilities more likely. However, it should be questioned if the investment in large centralized solar parks will be more beneficial than the investments by consumers in smaller solar photovoltaic facilities on site.

14/00863 Comparison of the safety criteria used for ground grid design at 161/23.9-kV indoor-type substation

Lee, C.-H. and Chang, C.-N. *International Journal of Electric Power & Energy Systems*, 2013, 49, 47–56.

This paper compares seven different standards, i.e. IEEE Std. 80, 2000 edition, IEC 60479–1, BS 7354, EA-TS 41–24, CENELEC HD 637 S1, DL/T 621 and ITU-T K.33 used for ground grid design at 161/23.9-kV indoor-type substation in the system of the Taiwan power company. The calculated results from equations proposed by Sullivan and the current distribution electromagnetic grounding and soil structure analysis (CDEGS) software package are also included. The results show IEC 60479–1 gives the lowest limits of tolerable touch and step voltages whereas BS 7354 gives the highest when no chippings on the ground surface are considered. The designed maximum predicted touch voltage obtained from Sullivan's equation is higher than those obtained from the formulas of BS 7354, EA-TS 41–24, DL/T 621 and CDEGS, the mesh voltage is higher than those from IEEE Std. 80, 2000 edition and CDEGS.

14/00864 Congestion management with distributed generation and its impact on electricity market

Singh, A. K. and Parida, S. K. *International Journal of Electric Power & Energy Systems*, 2013, 48, 39–47.

Congestion management became more complicated with the increase of complexity in the system. The complexity arose due to restructuring of the utilities alongside the penetration of alternative sources of energy. This paper presents a sensitivity method for allocating distributed generators (DGs) considering congestion relief and voltage security simultaneously. The sensitivities of the overloaded lines with respect to bus injections are considered for ranking the load buses. The new generation capacities for DGs connected at these load buses are then computed by genetic algorithm with an objective of enhancing the system performance by reducing the system losses and maintaining the voltage profile of the various buses nearest to its nominal value. The $N-1$ contingency criterion has been taken into account in this work. The expected cost consists of operating cost under normal and contingency states along with their related probabilities to occur. Maximizing social welfare is the objective for normal state while minimizing compensations for generations re-scheduling and load side operation as well as in case of contingency also. Though installation cost of DGs is required, they are useful as cost effective, which can reduce in fact the annual costs for generations re-scheduling and load shedding. It has been shown that the method can assist the independent system operator to remove the overload from lines in both normal and contingency conditions in an optimal manner. The improvement is measured in terms of available transfer capability, congestion cost and reliability risk indices of loss of load expectation have also been studied.

14/00865 Cost of PV electricity – case study of Greece

Fantidis, J. G. *et al. Solar Energy*, 2013, 91, 120–130.

The potential for a 20 kW photovoltaic (PV) power plant in Greece is examined in this study. HOMER software is used to predict energy production, cost of energy and reduction of greenhouse gasses (GHGs) emissions. The long-term meteorological parameters for 46 sites in Greece being considered by the Centre for Renewable Energy Sources and Saving are analysed. The global solar radiation varies between a minimum of 4.04 kW h/m^2/day in Ioannina and a maximum of 4.89 kW h/m^2/day in Tymbakion, while the mean value for the 46 locations remained as 4.46 kW h/m^2/day. The renewable energy produced each year from the PV power plant varied between 33.35 MW h in Ioannina and 41.63 MW h in Tymbakion while the average value for the 46 locations is 37.61 MW h. The results of the financial analysis demonstrate that a PV power plant can operate profitably at any of the considered sites in Greece. The capacity factor of a PV plant varies between 19.4% and 24.2% and the cost of electricity varies between €0.122 and €0.152/kW h from the most appropriate location to the least attractive location respectively. Bearing in mind that the electricity cost for consumers in Greece is approximately €0.13/kW h, the present study demonstrates that PVs can play an important role in Greek energy generation. Last but not least, utilization of PVs means that considerable quantity of CO_2 is not released into the local atmosphere each year.

14/00866 Demand response in smart electricity grids equipped with renewable energy sources: a review

Aghaei, J. and Alizadeh, M. A. *Renewable and Sustainable Energy Reviews*, 2013, 18, 64–72.

Dealing with renewable energy resources (RERs) requires sophisticated planning and operation scheduling along with state-of-the-art technologies. Among the many possible ways of handling RERs, demand response (DR) is investigated in this paper. Because of the every-other-year modifications in the DR definition and classification announced by the US Federal Energy Regulatory Commission, the latest DR definition and classification are scrutinized here. Moreover, a complete benefit and cost assessment of DR is added in the paper. Measurement and evolution methods along with the effects of DR in electricity prices are discussed. There is also a DR literature review of papers published after 2008. Finally, successful DR implementations from around the world are analysed.

14/00867 Determinants of residential electricity consumption: using smart meter data to examine the effect of climate, building characteristics, appliance stock, and occupants' behavior

Kavousian, A. *et al. Energy*, 2013, 55, 184–194.

This study proposes a method to examine structural and behavioural determinants of residential electricity consumption, by developing separate models for daily maximum (peak) and minimum (idle) consumption. The authors apply their method on a data set of 1628 households' electricity consumption. The results show that weather, location and floor area are among the most important determinants of residential electricity consumption. In addition to these variables, number of refrigerators and entertainment devices are among the most important determinants of daily minimum consumption, while number of occupants and high-consumption appliances such as electric water heaters are the most significant determinants of daily maximum consumption. Installing double-pane windows and energy-efficient lights helped to reduce consumption, as did the energy-conscious use of electric heater. Acknowledging climate change as a motivation to save energy showed correlation with lower electricity consumption. Households with individuals over 55 or between 19 and 35 years old recorded lower electricity consumption, while pet owners showed higher consumption. Contrary to some previous studies, the authors observed no significant correlation between electricity consumption and income level, home ownership, or building age. Some otherwise energy-efficient features such as energy-efficient appliances, programmable thermostats, and insulation were correlated with slight increase in electricity consumption.

14/00868 Distribution system optimisation with intra-day network reconfiguration and demand reduction procurement

Coroamă, I. *et al. Electric Power Systems Research*, 2013, 98, 29–38.

The evolution of distribution automation technologies and the advances in distribution system optimization studies are enabling the implementation of network configurations that are variable in time, with a limited number of configuration changes per day. The first part of this paper addresses the definition of pseudo-optimal intra-day distribution system configurations based on multi-scenario analysis handled with decision theory concepts. The resulting configurations are then used to formulate a demand response scheme for a given time period, aimed at procuring demand reductions to further decrease the distribution system losses. This scheme is driven by the calculation of the marginal loss coefficients and by the customers' willingness to participate in the demand response action. A dedicated offer scheme to be introduced in a benefit-based mechanism for optimal demand procurement is formulated and discussed.

14/00869 Electricity demand analysis and forecasting: a panel cointegration approach

El-Shazly, A. *Energy Economics*, 2013, 40, 251–258.

This article analyses the demand for electricity and provides out-of-sample forecasting at the sectoral level using a panel cointegration approach. The econometric model permits cross-sectional heterogeneity within a dynamic framework that incorporates information on relevant income and prices of domestic and foreign goods. Both the short-run dynamics and the long-run slope coefficients are allowed to vary across cross-sections. Also, the testing for unit roots and cointegration in panels allows for heterogeneous fixed effects and deterministic trends. Using Egyptian data, it is shown that the empirical model produces reliable *ex post* forecasts near the end of the full sample period. These pseudo forecasts are representative of what one would expect if the forecasting relationship is stationary. The long-run parameter estimates are then used to conduct *ex ante* forecasting under plausible assumptions for policy making.

14/00870 Energy subsidies, structure of electricity prices and technological change of energy use

Arias, A. D. and van Beers, C. *Energy Economics*, 2013, 40, 495–502.

This paper addresses the impact of the structure of energy prices on technological change in renewable energy sources. It operates on two fields of research that are often not related to each other. First, the increasing interest in environmental economics for the determinants of green technological change, and secondly the impact of government policies aimed at subsidizing energy prices. Recent research claims a positive relationship between energy prices and the number of patents in the fields of energy efficiency. This paper extends this research by investigating the impact of the price structure of electricity on patent counts in (1) renewable energy sources, (2) wind energy and (3) solar power. In nearly all OECD countries in the period 1990–2006 industrial energy users pay a lower price per energy unit than households due, among others, to government subsidy policies. The empirical results show that reducing government subsidies and hence increasing the electricity price of (large) industrial electricity users relative to the price paid by (small) residential users provides a clear incentive to increase inventions as measured by number of patents in the technical fields of solar and wind energy. These results are an important input in the debate on reducing government support to large energy users.

14/00871 How much room for a competitive electricity generation market in Portugal?

Amorim, F. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 103–118.

Although the Portuguese electricity market was fully liberalized in 2006 and Iberian electricity market operators were set up some years ago, almost all electricity generated in Portugal benefits from a state guaranteed price, independent of market behaviour. This applies not only to producers using renewable energy sources and cogeneration under feed-in tariffs, but also to all conventional power plants that undersigned a power purchase agreement in the 1990s. This paper shows that the volume and the duration of the existing legacy contracts prevent the development of a competitive wholesale market at least until the mid-2020s. In the mean time, given the foreseen development of the generation system, it will be important to address two main issues: balancing mechanisms to cope with 50% and more generation from renewable energy sources, and capacity incentives. Moreover, it is necessary to design an efficient wholesale market for the period after 2020, when a large number of fully depreciated, low variable cost power plants will dominate the generation landscape, in Portugal as well as in the Iberian Peninsula as this may represent barriers to entry of new investments. Price guarantees represent costs to be paid by electricity consumers during the following decades. Based on the data provided in this paper it will be possible to estimate the evolution of legacy costs to be supported by electricity consumers in the future.

14/00872 Impact of the Renewable Energy Sources Act in Germany on electricity produced with solid biofuels – lessons learned by monitoring the market development

Sauter, P. *et al. Biomass and Bioenergy*, 2013, 53, 162–171.

The increased use of renewable energy is the declared objective of the European and German climate policies. According to the German government, renewable energies will contribute to 35% of electricity production by 2020. In a bid to meet these ambitious targets, the Germany government implemented the EEG 2000. This policy guaranteed a fixed tariff for 20 years to all renewable energy plant operators providing electricity to grid. Following this policy implementation, significant market growth could be verified for nearly all renewable energy sectors. Approximately 20% of Germany's electricity today is met be renewables. In order to ensure an efficient growth and encourage technology providers to optimize and develop new innovative technologies a constant market monitoring and periodic amendments to the feed-in tariffs are required. In order to monitor the impact of the EEG and the development of the solid biofuels within the German energy supply system a comprehensive database with about 10,000 datasets has been accumulated over the past decade. This inventory database with various types of information is continuously updated, integrated and validated for data quality. It has emerged that this represents now the most complete and relevant database in Germany. Through the analysis of this database it can be shown, that the enactment of the EEG in 2000 has resulted in a 10-fold increase in the number, as well as in the installed capacity of biomass CHP plants. These biomass combined heat and power plants now contribute approximately 9% of the total electricity generated from renewable energy sources. The database analysis has also identified that there is a correlation between technology options, stakeholders and biomass sources, as these have changed in line with the changes in framework conditions over the last three EEG periods.

14/00873 Implications of liberalization policies on government support to R&D: lessons from electricity markets

Erdogdu, E. *Renewable and Sustainable Energy Reviews*, 2013, 17, 110–118.

Since the early 1980s, electricity industry reforms have been initiated in more than half of the countries in the world. Among the primary targets of these reform schemes there has been an increase in efficiency of the sector; and it is implicitly assumed that government support to energy technology R&D will progress in line with the reform process as the former is required to sustain improved efficiency in the middle and long run. The paper reviews the relation between reform process in electricity markets and government support to energy R&D. Using panel data from 27 countries, covering the period from 1974 to 2008, this study aims to find out to what extent the expected correlation between reform process and government support to energy R&D has materialized so far. The findings suggest that contrary to expectations, the progress toward electricity market reform is associated with reduced government support to a variety of energy R&D activities, which threatens sustainable efficiency improvements in the power industry.

14/00874 LMP decomposition: a novel approach for structural market power monitoring

Hajiabadi, M. E. and Mashhadi, H. R. *Electric Power Systems Research*, 2013, 99, 30–37.

This study decomposes and analyses the locational marginal price (LMP) for monitoring the ability of the generation companies (GenCos) to exercise market power. To achieve this goal, the electricity price discovery mechanism is restated and it is shown that the LMP at bus n (LMP_n) is composed of three components. The first is a constant value for each bus, while the second component includes the weighted summation of the strategies of the GenCos which not facing their generation caps, and the third component is composed of the weighted sum of generation of the units that facing their generation caps. The proposed decomposition produces important information regarding LMP. First, the weighting coefficients of the second and third terms indicate the sensitivity of LMP_n to the bidding strategies and generations of units. Furthermore, the decomposition of LMP_n to the constitutive components reveals the contribution of each GenCos to the electricity price at bus n. Hence, the weighting coefficients and the price components of the GenCos represent the potential for structural market power of the GenCos to the price discovery at each bus. The simulation results on the IEEE 24-bus test system illustrate the efficiency of the proposed monitoring approach.

14/00875 Monthly electric demand forecasting with neural filters

Jaramillo-Morán, M. A. *et al. International Journal of Electric Power & Energy Systems*, 2013, 49, 253–263.

Neural networks have proved to be a very efficient tool for time series forecasting. Furthermore, the structure of the neural model known as multilayer perceptron is well suited to behave as a digital filter. These two neural properties have been used to forecast the monthly electric demand. The corresponding time series has been split into two new series: one representing its trend and the other describing a fluctuation around that trend. Trend has been forecasted with a neural network, while fluctuation has been predicted by splitting its time series into six series associated to each of the six peak frequencies of the fluctuation spectrum, so that a filtering-forecasting process will be carried out by six neural networks to obtain six predictions. Then all the predictions have been added to obtain the monthly demand forecasting. It has been proved that a multilayer perceptron is able to perform both filtering and forecasting at once if properly trained.

14/00876 Multiscale Markov models with random transitions for energy demand management

Meidani, H. and Ghanem, R. *Energy and Buildings*, 2013, 61, 267–274.

A stochastic model is proposed for fluctuations in electricity demand that are associated with individual user's consumption choices. Electricity consumption is modelled as a function of social activities of consumers. The dynamics of these activities are modelled as a Markov chain. Markov models are simplified models that capture the stochasticity to the unmodelled dynamics typically attributed to white noise disturbances. Additional uncertainties are also accrued in the process of calibrating the transition rates of these chains from finite samples. In this paper, these uncertainties are accounted for by considering random transition matrices. Such formalism can also reflect the fluctuations in the environment in which the chain evolves. The authors also discuss a third interpretation where uncertain transitions, in a multiscale setting, reflect the fine-resolution information that is lost in the process of state aggregation. As numerical demonstration, the authors study the activity modelling of a heterogeneous population. Activity uncertainties are propagated onto the energy demand. Demand uncertainties, in turn, are propagated onto a global performance metric. Such uncertainty management framework bridges between the actual drivers of the energy consumption and the system health. Subsequent decisions can be robustly supported based on the results of the quantitative model proposed in this paper.

14/00877 Optimal distributed renewable generation planning: a review of different approaches

Tan, W.-S. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 626–645.

Distributed generation has gained a lot of attention in the power sector due to its ability in power loss reduction, increased reliability, low investment cost, and most significantly, its ability to exploit renewable-energy resources, which produce power with minimum greenhouse gas emissions such as wind power, photovoltaics and micro turbines. Installation of distributed generation at a non-optimal location can result in various problems such as an increase in system losses and costs, voltage rise and fluctuations, reliability and stability problems. Therefore, it is necessary to develop an optimization or heuristic technique methodology to identify the optimal placement of distributed renewable generation for a given system that can provide economic, environmental and technical advantages. There have been several papers that study the optimal distributed renewable generation location by their imposed constraints and objectives. However, the systematic principle for this issue is still an unsolved problem. This paper reviews some of the most popular distributed renewable generation placement methods, including the two-thirds rule, analytical methods, optimal power flow, mixed integer non-linear programming, various types of artificial intelligent optimization techniques and hybrid intelligent system. Each methodology has its own features and potential for significantly promoting the applicability of distributed renewable generation in power systems.

14/00878 Process systems opportunities in power generation, storage and distribution

Soroush, M. and Chmielewski, D. J. *Computers & Chemical Engineering*, 2013, 51, 86–95.

This paper presents an overview of the current process systems opportunities in power generation, storage and distribution. It puts in perspective how process systems engineering (PSE) has contributed to the area and explores the current technical problems that PSE can contribute to. Fuel cells, solar cells, wind turbines, flow batteries and rechargeable batteries as well as their interactions with the smart grid are considered. PSE has contributed and will contribute to the design as well as optimal integration and operation of power generators, storage systems and power grids, through mathematical modelling, control and optimization.

14/00879 Risk-based optimal bidding strategy of generation company in day-ahead electricity market using information gap decision theory

Nojavan, S. and Zare, K. *International Journal of Electric Power & Energy Systems*, 2013, 48, 83–92.

This paper considers a price-taker generation company to participate in day-ahead electricity energy market. While making optimal bidding strategy for producer, factors such as the characteristics of generator and the market price uncertainty need to be considered because of having direct impact on the expected profit and bidding curve. The market price considered an uncertain variable and it is assumed that the generation company forecasted the market prices. In this study, the uncertainty model of market price is considered based on the concept of weighted average squared error using a variance–covariance matrix. Information gap decision theory is used to develop the bidding strategy of a generation company. It assesses the robustness/opportunity of optimal bidding strategy in the face of the market price uncertainty while producer considers whether a decision risk-averse or risk-taking. It is shown that risk-averse or risk-taking decisions might affect the expected profit and bidding curve to day-ahead electricity market. A case study is used to illustrate the proposed approach.

14/00880 Stochastic generation-expansion planning and diversification of energy transmission paths

Pantoš, M. *Electric Power Systems Research*, 2013, 98, 1–10.

The paper addresses a stochastic generation-expansion planning model in the interdependent operation of an electric power system (EPS) and a natural gas system (NGS). The objective of the proposed optimization model is to provide consumers with a reliable electric energy supply by proper generation-expansion planning and diversification of energy transmission paths with minimal investment and operating costs. The proposed method takes into account constraints in the EPS and NGS. The Monte Carlo simulation method is applied to consider random outages of EPS and NGS elements and inaccuracies in the long-term electric load forecasting. A scenario reduction technique is used for reducing the computational burden of a large number of planning scenarios. The EPS and NGS are presented by a direct current model and a transportation model. The optimization problem is decoupled into a master problem and a subproblem using the Benders decomposition to cope with large-scale problems. The master problem deals with the optimization of investment in new generation units and energy transmission paths. The subproblem comprises a two-level optimization with a decomposed EPS reliability check as the master problem of the subproblem, and a NGS reliability check as the final subproblem. The case studies illustrate the applications of the proposed stochastic method in a coordinated generation-expansion planning problem when considering uncertainties.

14/00881 The impact of attribute preferences on adoption timing: the case of photo-voltaic (PV) solar cells for household electricity generation

Islam, T. and Meade, N. *Energy Policy*, 2013, 55, 521–530.

This study is concerned with micro-generation, individual households generating electricity using a renewable technology. The authors focus on modelling the adoption probability of photo-voltaic solar panels by households. Using data from Ontario, Canada where a generous feed-in-tariff is available to households generating electricity from solar panels, the authors measure household level preferences for panels and use these preferences along with household characteristics to predict adoption time intentions. The authors use discrete choice experiments to measure household level preferences and establish a causal link between the attributes of the technology and adoption time intentions using discrete time survival mixture analysis. Significant preferences included lower cost, greater energy savings and lower fossil fuel inflation. The conditional (hazard) probability of adoption at a particular time given no previous adoption showed that the attribute preferences had intuitively reasonable effects. The hazard probabilities allow us to compute the cumulative probability of adoption over a 10-year period per household. Technology awareness has a significant effect on the adoption probability, reinforcing the need for effective education. This approach indicates the level of heterogeneity in preferences, particularly high for investment criteria and CO_2 emissions. These findings suggest that education campaigns should explain more about investment criteria, feed-in tariffs and environmental effects.

14/00882 The role of grid extensions in a cost-efficient transformation of the European electricity system until 2050

Fürsch, M. *et al. Applied Energy*, 2013, 104, 642–652.

A strong and intermeshed electricity grid allows the cost-efficient achievement of renewable energy targets by enabling the use of favourable sites and by facilitating the balancing of stochastic in-feed from renewables and electricity demand. However, construction of new lines is currently proceeding slowly in Europe. This paper quantifies the benefits of optimal transmission grid extensions for Europe up to 2050 by iterating an investment and dispatch optimization model with a load flow based grid model. It was found that large grid extensions, allowing the full exploitation of the most favourable RES-E sites throughout Europe, are beneficial from a least-cost perspective. If the electricity network were to be cost-optimally extended, 228,000 km would be built before 2050 (+76% compared to today). Only for sites located furthest from large consumption areas in Central Europe would the value of grid extensions not always outweigh its costs. Furthermore, the capacity of transmission lines connecting favourable RES-E sites with demand centres is cost-optimally dimensioned to almost entirely export all RES-E generation that exceeds local electricity demand. Only in periods with the highest in-feed of fluctuating renewables, electricity is stored. When optimal grid extensions are impeded, storage investments are chosen to a larger extent.

14/00883 Using artificial neural networks to predict the impact of daylighting on building final electric energy requirements

da Fonseca, R. W. *et al. Energy and Buildings*, 2013, 61, 31–38.

Daylighting has a recognized potential for electric energy savings when used as a complement for artificial lighting. Recent studies have indicated that artificial neural networks (ANNs) present high potential for daylighting analysis in buildings. In this study, a statistical performance method based on ANNs is evaluated. The ANN use is assessed in comparison with the multivariate linear regression (MLR) technique in order to represent the potential for energy savings through the daylighting use in office buildings. The data set was based on computer simulation results obtained with 216 models and used to develop a MLR equation. The simulations were performed with Daysim (daylighting) coupled to EnergyPlus (energy). In parallel, an approximation model using ANN was applied. The method adopted for the training and validation of the ANN was a cross-validation procedure, recommended for limited data sets. The results demonstrate that the ANN have shown a better performance in representing this problem, since it presented a lower coefficient of determination and an acceptable mean square error. In addition, the ANNs presented learning skills which allow them to perform the generalization process in a better way. After being validated, the ANN is expected to provide output results for input data which have not yet been submitted to it, providing reasonable estimates of daylighting impact on electric energy need for new environments.

07 STEAM RAISING

Boiler operation/design

14/00884 A method to target and correct sources of unburned carbon in coal-fired utility boilers

Gao, H. *et al. Fuel*, 2013, 108, 484–489.

This study presents a novel method to examine particle burnout in coal-fired utility boilers by extracting information from computational fluid dynamics (CFD) model results. The direct targeting of underlying causes enabled by this method can provide dramatic improvement in the unburned carbon in fly ash (carbon-in-ash or CIA), improving the commercial value of the ash as an additive in the production of concrete and cement and improving boiler efficiency. Data for thousands of particles are extracted and summarized for engineering characteristics such as injection burner, particle size, residence time, and exposure to oxygen. As an example of the method, unburned carbon is studied for a 200 MWe tangentially-fired utility boiler with CIA issues. The analysis, which is consistent with boiler operation data, reveals that a majority of CIA can be contributed by a disproportionately small number of sources, hence the advantage of a targeted approach. The analysis of the 200 MW boiler reveals that fewer than half of the burners contribute about 80% of the CIA and the two largest coal particle size classes contribute 70% of the CIA. Most importantly, however, the oxygen availability for the coal particles is found to be the key factor for coal burnout. Based on this result, a simple and targeted strategy to improve burnout by improving oxygen availability is designed. This method is predicted by the model to reduce CIA from 3.27% to 1.3% and NO_x from 588 to 503 ppm.

14/00885 A new screening tool for evaluation of steamflooding performance in naturally fractured carbonate reservoirs

Shafiei, A. *et al. Fuel*, 2013, 108, 502–514.

Appropriate production method selection for viscous oil (e.g. heavy oil, extra heavy oil, and bitumen) naturally fractured carbonate reservoirs (VO NFCRs) mostly depends on the quality of the fluid and reservoir properties. Selection of a particular production method for a reservoir is generally evaluated through an exhaustive experimental, field pilot, and mathematical modelling approach. In the absence of robust and quick predictive tools, using connectionist techniques for performance prediction of a particular production method can be a valuable asset. In this study, a new screening tool is developed based on artificial neural networks (ANNs) optimized with particle swarm optimization (PSO) to assess the performance of steamflooding in VO NFCRs. As expected, recovery factor (RF) and cumulative steam to oil ratio (CSOR) during steamflooding are highly affected by the magnitudes of oil saturation and viscosity. The developed PSO–ANN model, conventional ANN and statistical correlations were examined using real data. Comparison of the predictions and real data implies the superiority of the proposed PSO–ANN model with an absolute average error percentage <6.5%, a determination coefficient (R^2) > 0.98, and mean squared error <0.06, in contrast with conventional ANN model and empirical correlations for prediction of RF and CSOR. This indicates a great potential for application of hybrid PSO–ANN models to screen viscous oil carbonate reservoirs for steamflooding.

14/00886 Combustion and emission characteristics of a domestic boiler fired with pellets of pine, industrial wood wastes and peach stones

Rabaçal, M. *et al. Renewable Energy*, 2013, 51, 220–226.

This study evaluates the combustion and emission characteristics of a domestic boiler fired with pellets of pine, industrial wood wastes and peach stones. Initially, the boiler performance, firing pine pellets, was evaluated as a function of the thermal input. Subsequently, the influence of the pellets type on boiler performance was also examined. The results reveal that the type of pellets affects significantly the boiler emissions characteristics, with the pine pellets performing significantly better than the pellets of industrial wood wastes and peach stones. The boiler thermal efficiency is not negatively affected when fired with the pellets of industrial wood wastes and peach stones. Typical operating conditions of the boiler are not suitable for the use of wood wastes and peach stones pellets as CO and HC emissions are superior. The pellets of industrial wood wastes and peach stones have, however, an attractive potential for use in domestic boilers, through the optimization of the boiler operating conditions, being this a sustainable means of energetic valorization of residues with no specific use.

14/00887 Estimation of residual life of boiler tubes using steamside oxide scale thickness

Vikrant, K. S. N. *et al. International Journal of Pressure Vessels and Piping*, 2013, 104, 69–75.

In thermal power plants, remaining-life-estimation of boiler tubes is required at regular intervals for a safer and a better functionality of boilers. In this paper, a new method is proposed for the residual life estimation of service exposed boiler tubes using non-destructive ultrasonic oxide scale thickness measurements, average metal temperature and creep master curve. While steady-state conduction heat transfer equations are solved to calculate the average metal temperature, creep master curve is generated from short term stress rupture data of rupture life less than 5000 h on a virgin material. In the present study, the residual life of T22 (2.25Cr–1Mo) service exposed platen superheater tube is estimated using two master creep curves, i.e. Larson–Miller parametric method of standard ASME T22 creep data and Wilshire approach of short term stress rupture data of T22. As the residual life is calculated from fundamental conduction heat transfer theory and creep rupture data, the proposed method can be applied for different grades of boiler materials.

14/00888 Evaluation on cold modeling flow field for a down-fired 600 MWe supercritical boiler with multi-injection and multi-staging: a burner location experimental optimization and its validation by real-furnace measurements

Kuang, M. *et al. Experimental Thermal and Fluid Science*, 2013, 45, 213–220.

This work presents a burner location optimization by cold modelling experiments and its validation by real-furnace measurements for a new down-fired 600 MW_e utility boiler with a low-NO_x combustion technology. By recording flow field measurements within a 1 : 20-scaled model of the furnace, cold airflow experiments were conducted at various burner location settings, i.e. the ratio (denoted by C_l) of the distance between the burner centreline and the front (rear) wall to the arch depth is 35%, 39%, 42%, 46% and 49%, respectively. Meanwhile, at normal full load industrial-size experiments were performed with measurements taken of gas temperatures in the near wing-wall region, carbon content in fly ash, and NO_x emissions. At settings of 35% and 39%, flow field and velocity distributions along certain cross-sections as well as penetration depths of downward airflows were well-formed symmetric along the furnace centre. At the left three higher settings, a deflected flow field appeared in the lower furnace, with the downward airflow near the rear wall being directed upward earlier than that near the front wall. With increasing the C_l value from 42% to 49%, the flow-field deflection became turbulent. To establish a symmetric flow field along with an appropriate airflow penetration depth, a burner location setup of $C_l = 39\%$ was finally installed in the furnace. As expected, industrial-size data revealed that with the optimized burner location, excellent furnace performance characterized by symmetric combustion, good burnout, and low NO_x emissions, appeared within the furnace.

14/00889 Experimental study of the characteristics of steam jet pump and effect of mixing section length on direct-contact condensation

Shah, A. *et al. International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 62–69.

Steam jet pump (SJP) is a simple mechanical device and may be regarded as the most suitable pump for pumping hazardous liquids because of its mechanical simplicity, no maintenance, simple control, etc. In this study, an experimental setup of SJP was developed in which the mixing section was made transparent for flow visualization. The effect of the mixing section length on the transport process in SJP has been studied using three different lengths of the mixing section (110, 130 and 150 mm). Moreover experiments were performed to study the suction characteristics of SJP at various operating conditions. Better performance was observed in the SJP geometry with shorter length of the mixing section. A new concept of interface vibration process in direct-contact condensation (DCC) of SJP was introduced using the experimental results. An effort has been made to explain the process of DCC in SJP using the concept of interface vibration process. The performance characteristics of SJP have also been studied in the light of interface vibration process in DCC of SJP.

14/00890 Leak behavior of steam generator tube-to-tubesheet joints under creep condition: experimental study

Bahn, C. B. *et al. International Journal of Pressure Vessels and Piping*, 2013, 101, 55–63.

To address concerns regarding excessive leakage from throughwall cracks in steam generator tube-to-tubesheet joints under severe accident conditions, leak rate testing was conducted using tube-to-collar joint specimens. The tube interior and the interface between tube and collar (crevice) were pressurized independently using nitrogen gas. The leak rate through the crevice was almost zero when the specimens were pressurized at ~500 °C; this low leak rate is attributed to thermal mismatch effects preventing much leakage. The near zero leak rate was maintained until the onset of large leakage at higher temperatures. The leak rate behaviour after the onset of the large leakage was not much affected by the crevice length or heat-to-heat variation of Alloy 600 tubes. This suggests that once the crevice gap opens, the creep rate of the low alloy steel collar becomes dominant. Specimens with different tube diameters behaved essentially the same way. To simulate a flawed steam generator tube in the tubesheet, the crevice region was pressurized through a hole in the tube. This simulation resulted in essentially the same behaviour as those specimens whose tubes and crevices were pressurized independently. Oxidation of low alloy steel collars in air tests can increase the flow resistance, and thus tests using nitrogen gas would provide more conservative leak rate data.

14/00891 Leak behaviors of steam generator tube-to-tubesheet joints from room temperature to 320 °C

Bahn, C. B. *et al. International Journal of Pressure Vessels and Piping*, 2013, 101, 45–54.

To address concerns about excessive leakage from throughwall cracks in nuclear reactor tube-to-tubesheet joints under accident conditions, leak rates were measured experimentally by using tube-to-collar joint specimens and nitrogen gas. Rates were dependent on differential pressure between the tube internal surface and the crevice (i.e. the tube-to-collar interface region) and on temperature. As specimen temperature was raised to 320 °C, leak rates decreased gradually due to changes in gas properties and to differential thermal expansion between the Alloy 600 tubes and the SA508 collars. The leak rates did not change even after repeated temperature excursions to 320 °C, suggesting that thermally induced creep and subsequent contact pressure relaxation is negligible below that temperature. When considering factors that could increase flow resistance, such as oxidation, or debris on top of the tubesheet, the measured leak rates in this work are considered to be conservative. The test results were further used to validate the contact pressure calculation and a leak rate model.

14/00892 Mathematical modeling of sulfur deactivation effects on steam reforming of producer gas produced by biomass gasification

Sadooghi, P. and Rauch, R. *Fuel Processing Technology*, 2013, 110, 46–52.

Product gas produced by biomass gasification contains small amounts of sulfur compounds (hydrogen sulfide) which can reduce catalyst activity during steam reforming process. Sulfur removal has a negative effect on process efficiency and steam reforming has to be run without cleaning the gas prior to the reactor. It is therefore of interest to investigate the effect of sulfur on the performance of steam reforming reactions. In this work a packed bed reactor filled with nickel-based catalysts is mathematically modelled to simulate the steady state pseudo-heterogeneous equations representing heat and mass transfer in the reactor tube. Catalytic bed is subjected to hydrogen sulfide and an isotherm model for the sulfur coverage on the Ni surface is considered to exactly investigate sulfur poisoning effects on methane conversion, hydrogen yield, carbon dioxide and carbon monoxide concentration. It is shown that even when present in the hydrocarbon feedstock in small quantities (ppm) levels, sulfur can have a significant effect in methane conversion and temperature distribution within the reactor.

14/00893 Numerical investigation on combustion and NO_x emissions of a down-fired 350 MW_e utility boiler with multiple injection and multiple staging: effect of the air stoichiometric ratio in the primary combustion zone

Kuang, M. *et al. Fuel Processing Technology*, 2013, 109, 32–42.

A new down-fired combustion technology based on multiple-injection and multiple-staging was previously developed for a down-fired 350 MW_e utility boiler suffering from severely asymmetric combustion and particularly high NO_x emissions. To evaluate its furnace performance with respect to the new technology, coal combustion process and NO_x formation within the furnace were numerically investigated at four settings (i.e. air stoichiometric ratios in the primary combustion zone (SR_p) of 1.02, 0.96, 0.90, and 0.84, respectively). Numerical results uncovered that with the new technology replacing the prior art, asymmetric combustion removals and significant NO_x reductions (nearby 50%) were validated for all four settings. With decreasing SR_P, both gas temperature at the furnace outlet and O_2 in flue gas decrease continuously, carbon in fly ash generally increases, while NO_x emissions decrease initially but then increase. In considering relatively appropriate values established simultaneously in gas temperature at the furnace outlet, O_2 in flue gas, carbon in fly ash, and NO_x emissions when $SR_p = 0.96$ and 0.90, the optimum operation condition for the furnace after a retrofit with the technology was recommended at $SR_p = 0.90$–0.96.

14/00894 Numerical study of hydrogen production via sorption-enhanced steam methane reforming in a fluidized bed reactor at relatively low temperature

Chen, Y. *et al. Chemical Engineering Science*, 2013, 92, 67–80.

Production of hydrogen by sorption enhanced methane steam reforming (SE-SMR) process at a relatively low temperature in a two-dimensional cylindrical bubbling fluidized bed reactor was studied using an Eulerian–Eulerian approach. The study aims to investigate the influence of operating pressure, superficial velocity, catalyst-to-adsorbent ratio (C/A, weight) and sorption kinetics on the SE-SMR process. A H_2 concentration of >87% on a dry basis can be obtained at 500 °C and 0.1 MPa using hydrotalcite-like compounds (HTC) as CO_2-acceptor. A relatively low catalyst-to-adsorbent ratio (~0.5) is preferable for reducing operating cost and enhancing hydrogen production. Higher operating pressure is favourable for the utilization of sorbent, but unfavourable for the conversion of methane. Simulations prove that sorbents with slow kinetics can only serve as CO_2 acceptor, but cannot enhance the methane steam reforming process effectively. Another interesting observation is that the way the superficial velocity affects the CO_2 capture efficiency is determined by the sorption kinetics. For HTC, it is the bigger bubble size rather than the reduction of gas residence time that mainly accounts for the decrease of the CO_2 capture efficiency under higher velocities investigated.

14/00895 Pseudo heterogeneous modeling of catalytic methane steam reforming process in a fixed bed reactor

Sadooghi, P. and Rauch, R. *Journal of Natural Gas Science and Engineering*, 2013, 11, 46–51.

A mathematical model is developed to simulate synthesis gas production by methane steam reforming process in a fixed bed reactor filled with catalyst particles. Due to the endothermic nature of the reforming reactions heat is supplied into the reactor by means of electrical heating, therefore, the reactor and catalyst particles are exposed to significant axial and radial temperature gradients. A pseudo heterogeneous model is used in order to exactly represent diffusion phenomena inside the reactor tube. Heat and mass transfer equations are coupled with detailed reaction mechanisms and solved for both the flow phase and within the catalyst pellets. The reaction has been investigated from a modelling viewpoint considering the effect of different temperatures ranging from 873 to 1073 K on methane conversion and hydrogen yields. The result provides temperature and concentration distribution along the reactor axial and radial coordinates and strong radial temperature gradients particularly close to the entrance of the reactor have been found.

14/00896 The thermal efficiency improvement of a steam Rankine cycle by innovative design of a hybrid cooling tower and a solar chimney concept

Zandian, A. and Ashjaee, M. *Renewable Energy*, 2013, 51, 465–473.

In this study, a dry cooling tower and a solar chimney design are recombined in order to increase the thermal efficiency of a steam Rankine cycle. The rejected heat from the condenser into the dry cooling tower supplemented by the solar radiation gained through its transparent cover are the sources of wind energy generation that is captured by a wind turbine which is located at the beginning of the chimney. In this research a case study for a 250 MW steam power plant of Shahid Rajaee in Iran has been performed. A computational fluid dynamics finite volume code is developed to find the generated wind velocity at the turbine entrance for a 250 m dry cooling tower base diameter and a chimney height of 200 m. Calculations have been iterated for different ambient temperatures and solar irradiances, representing temperature gradient within day length. Power, ranging from 360 kW to 3 MW, is obtained for changes in the chimney diameter from 10 to 50 m. The results show a maximum of 0.37% increase in the thermal efficiency of a 250 MW fossil fuel power plant unit. This shows that this design is a significant improvement in efficiency of thermal power plants by capturing the heat that is dissipated from dry cooling towers.

14/00897 Thermal–hydraulic simulation of a radiant steam boiler using Relap5 computer code

Amina Lyria, D. C. *et al. Computers & Chemical Engineering*, 2013, 52, 168–176.

Numerical simulations are nowadays increasingly used to assess the thermal–hydraulic behaviour of a steam boiler instead of carrying out expensive tests in experimental facilities. In the present work, the Relap5/Mod3.2 thermal–hydraulic computer code, which is largely used in the nuclear engineering framework, is used to carry out a tube rupture transient of a high power industrial steam boiler. For this purpose a Relap5 model was developed and qualified at the steady-state conditions using the plant available data. The control and regulation systems are also modelled. The main outcome of this work is a successful application of a thermal–hydraulic system code in predicting the main key parameters of an industrial radiant steam boiler under steady and transient operating conditions.

08 COMBUSTION

Burners, combustion systems

14/00898 2D effects in laminar premixed flames stabilized on a flat flame burner

Konnov, A. A. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 213–223.

In this study, non-idealities of flat burner-stabilized flames at atmospheric and low pressures are examined using particle image velocimetry measurements, which are supported by and analysed with the help of computational fluid dynamics modelling. Radial and axial velocity profiles measured in the cold flow and in the flames at atmospheric and at lower pressures are presented. Two possible reasons for the drop in the apparent laminar burning velocity at low pressures (<20 kPa) were considered: the non-uniformity of the velocity profile issuing from the burner mouth and diffusion of the gas mixture from the original gas flow. At very low pressures an outward velocity at the edge of the burner plate is detected. A part of the fuel–air mixture therefore seems to escape the flow at the edge of the burner. Further experiments, however, revealed that diffusion of the fuel from the fresh mixture and of the ambient atmosphere into the flame is less important as compared to the diffusive loss of hydrogen atoms from the flame at low pressures. This was substantiated by the numerical analysis and assessment of the earlier observations from the literature. A critical relation between the size of the burner and the lowest pressure for ensuring the stabilization of a flat flame is demonstrated.

14/00899 A new innovative CFD-based optimisation method for biomass combustion plants

Shiehnejadhesar, A. *et al. Biomass and Bioenergy*, 2013, 53, 48–53.

In this paper, the work on the development and test of a basic design tool for the automatic performance of parameter studies for the optimization of biomass combustion plants is presented. The model consists of parameterization and optimization routines linked with an in-house developed empirical packed bed combustion model as well as gas-phase computational fluid dynamics (CFD) models especially adapted for biomass grate furnaces. To test and verify the routine developed, it has been applied to the optimization of a 180 kW_{th} pilot-scale grate furnace. The main focus was on the minimization of CO emissions and the pressure loss by changing the diameter and angle of the secondary air nozzles. The simulation results show that the time of the optimization process can be reduced considerably by the automatic routine developed and the evaluation of several independent design parameters is possible. This new procedure forms an important milestone towards automatic CFD-based furnace and boiler optimizations in the future.

14/00900 A novel framework for the quantitative analysis of high resolution transmission electron micrographs of soot I. Improved measurement of interlayer spacing

Toth, P. *et al. Combustion and Flame*, 2013, 160, (5), 909–919.

The reliable and reproducible quantitative image analysis of digital micrographs from high-resolution transmission electron microscopy (HRTEM) of soot has been an area of interest since the early nineties. Since the resolution of HRTEM images is usually sufficient to carry out structural measurements at the atomic level, the information obtained from these images is very valuable as it potentially yields insight into very specific soot oxidation processes; however, extracting physically meaningful, reliable, accurate and statistically robust data from HRTEM images is not an easy process. Data extraction is hindered by the presence of overlapping structures, varying focus, contrast, illumination levels and noise in the images. In this paper a novel image analysis framework is presented to address these issues and explore the possibility of the extraction of high-fidelity structural data from HRTEM soot images. Emphasis is on the analysis of images of mostly amorphous, poorly ordered soot structures, as these are the most difficult to analyse.

14/00901 A novel framework for the quantitative analysis of high resolution transmission electron micrographs of soot II. Robust multiscale nanostructure quantification

Toth, P. *et al. Combustion and Flame*, 2013, 160, (5), 920–932.

The quantitative characterization of mostly amorphous soot structures is a difficult problem. High-resolution electron microscopy is a tool capable of providing structural information related to the crystalline order in soot; however, well-defined and exhaustive structural parameters are needed for quantification. The typical observable field of view and the insufficient amount of structural information extractable from a single electron micrograph pose another problem in obtaining reliable statistical description. This paper has two objectives: first, to show that the already developed and published structural descriptors can be united by introducing a general model for the characterization of molecular order and second, to extend the general filtering approach presented in the first part of this study to allow for the efficient extraction of such general parameters. The computational background is described with automatic, real-time future applications in mind.

14/00902 Combustion of hydrogen rich gaseous fuels with low calorific value in a porous burner placed in a confined heated environment

Francisco Jr., R. W. *et al. Experimental Thermal and Fluid Science*, 2013, 45, 102–109.

This study investigates the combustion of gaseous fuels with low calorific value in a porous burner placed in a confined heated environment, established by a laboratory-scale furnace, with temperature-controlled, isothermal walls. It examines the effect of the composition of the fuel mixtures and of the furnace temperature on flame stability and pollutant emissions. Mixtures of CH_4, H_2 and CO diluted with CO_2 and N_2 were used as low calorific value fuels. The composition of the fuel mixtures was tailored such that the constant pressure adiabatic flame temperature at the equivalence ratio 0.5 remained at 1207 °C while the lower calorific values varied from 4.5 to 50 MJ/kg. The present results reveal that the upper stability limit was reduced by about 15% as compared with that in open environment. However, in both environments was observed that the hydrogen concentration in the fuel mixture enlarges the burner stability range. For methane concentrations in the fuel mixture higher than 40%, the stability limits do not vary appreciably. The pollutant emissions were measured in both open and confined environments. As the furnace temperature increases the CO and HC emission indexes decrease significantly.

14/00903 DNS analysis of a three-dimensional supersonic turbulent lifted jet flame

Luo, K. *et al. Fuel*, 2013, 108, 691–698.

A fully compressible solver for direct numerical simulation of supersonic combustion has been developed and applied to investigate a three-dimensional spatially developing supersonic turbulent jet flame. High-resolution bandwidth-optimized weighted essentially non-oscillatory scheme of spatial discretization and total variation diminishing temporal integration are used to capture the intricate phenomena with an accurate characteristic system and an updated detailed H_2/air reaction mechanism. The numerical algorithms are first validated by simulating some canonical problems, and then used to analyse the global features, compressibility effects, and the stabilization mechanism of the supersonic lifted jet flame. It is found that the lifted flame consists of a stable laminar flame base with auto-ignition as the stabilization mechanism, a violent mixing region in which vigorous turbulent combustion occurs with both premixed and diffusion flames, and a far-field outer diffusion flame as well as an inner weaker premixed flame. Although diffusion combustion dominates the flame in general, premixed combustion is significant within the violent mixing region. The heat release rate in the high-speed region can be significantly influenced by the compressibility. In the region of fuel compressing, the heat release rate increases as the compressive power increases. While in the region of fuel expanding, the heat release rate also increases as the expansive power increases albeit with a smaller magnitude. The auto-ignition in a fuel-lean mixture near the most reactive condition is the main stabilization mechanism, which is determined from the statistical analysis of the heat release rate and the Damköhler number as well as the deduction of the lift-off height of the flame.

14/00904 Effect of the momentum flux ratio of vertical to horizontal component on coal combustion in an arch-fired furnace with upper furnace over-fire air

Zhao, S. *et al. Experimental Thermal and Fluid Science*, 2013, 45, 180–186.

Over-fire air is introduced to achieve deep staging conditions for combustion optimization in a 0.7 MW arch-fired furnace. The momentum flux ratio (*M*) of vertical to horizontal component is determined by variations of air distribution and the inclination angle of the F-layer secondary air. Two coals with relatively large characteristic differences are used in the pilot tests. The results show that *M* directly affects the arch air penetration length and the position of the flame centre. As the inclination angle increases appropriately, the position of high-temperature zone moves downward, and the variation amplitude becomes smaller. The distribution of the wall temperature becomes more uniform. An overlarge angle would cause severe dregs on the wall of hopper, however. Increasing the arch air ratio can also delay the mixing of air–fuel flows and stage air and lower downward the flame centre. Too small *M* would cause much higher temperatures in the upper furnace. The unburned carbon in the fly ash and NO_x emission both attain their minimum values with an inclination angle of 30° and a momentum flux ratio of 1.35, which is considered as the optimum operation condition in the experimental range.

14/00905 Evaluation of the sooting properties of real fuels and their commonly used surrogates in a laminar co-flow diffusion flame

Witkowski, D. *et al. Combustion and Flame*, 2013, 160, (6), 1129–1141.

In an effort to help determine the fidelity of simple surrogate fuels to represent real fuel chemistry in computational fluid dynamic simulations of engines, quantitative two-dimensional soot volume fraction measurements were made in a laminar coflow methane–air diffusion flame seeded with approximately 2200 ppm of real and surrogate fuels. A combined laser extinction and laser-induced incandescence (LII) method was used to measure soot volume fraction. Additionally, soot particles were thermophoretically sampled from the flame and soot morphology data were collected with a transmission electron microscope. Vaporized liquid fuels were seeded at low concentrations to maintain constant thermodynamic conditions for each experiment. In all, 14 different fuels were investigated, including: three real fuels (gasoline, diesel and jet fuel), two alkanes, and a variety of simple surrogate fuels. A toluene reference fuel (30% aromatics) and gasoline (28% aromatics) were found to have similar soot volume fractions and soot morphology. The addition of toluene to the long-straight chain of *n*-tetradecane in similar concentrations (30 vol.%) as the aromatic concentration of diesel (31.1 vol.%) resulted in soot volume fractions that were very similar, although the primary particle size and mass-weighted radius of gyration were both smaller for the surrogate than for the conventional diesel fuel. Finally, the jet fuel surrogate tested was found to have a lower sooting tendency than the jet-A fuel despite the jet-A fuel having a lower concentration of aromatics than the surrogate. Soot morphology between jet-A and the jet fuel surrogate were the same within experimental uncertainty. The current work provides an experimental dataset for validation of fuel-surrogate chemistry and soot models.

14/00906 Experimental investigation of co-combustion of coal and biomass using chemical looping technology

Luo, M. *et al. Fuel Processing Technology*, 2013, 110, 258–267.

An experimental investigation into direct chemical looping combustion (CLC) was carried out using Yimin coal and two kinds of biomass, i.e. candlenut wood and rice hull as solid fuels and CuO as oxygen carrier. A series of tests was conducted in a thermogravimetric analyser (TGA) to simulate the direct CLC process using coal, biomass, and their co-combustion, respectively. The synergetic effect between coal and candlenut wood was observed during the co-combustion process, but it was not found between coal and rice hull. The addition of K_2CO_3 and candlenut wood ash decreased the gasification temperature and increased the coal conversion. The theoretical coal conversion when 80 wt% candlenut wood ash was added was similar to that when 50 wt% K_2CO_3 was added. The high reactivity and stability of CuO was observed during cyclic operation at 800 °C. The interactions between metal oxide and ash were detected and no new phases were found after redox processes. Some changes appeared in the surface morphology of CuO–soild fuel samples after redox reactions, but no severe surface sintering was observed. Therefore, experiments and data analyses prove that CuO-based oxygen carrier was suitable for CLC of solid fuels. Some crucial considerations for the combustor operation were also given.

14/00907 Experimental investigation of spark ignition energy in kerosene, hexane, and hydrogen

Bane, S. P. M. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 290–294.

Quantifying the risk of accidental ignition of flammable mixtures is extremely important in industry and aviation safety. The concept of a minimum ignition energy (MIE), obtained using a capacitive spark discharge ignition source, has traditionally formed the basis for determining the hazard posed by fuels. While extensive tabulations of historical MIE data exist, there has been little work done on ignition of realistic industrial and aviation fuels, such as gasoline or kerosene. In the current work, spark ignition tests are performed in a gaseous kerosene–air mixture with a liquid fuel temperature of 60 °C and a fixed spark gap of 3.3 mm. The required ignition energy was examined, and a range of spark energies over which there is a probability of ignition is identified and compared with previous test results in Jet A (aviation kerosene). The 'go' (ignition) and 'no go' (no ignition) data points were found to overlap, indicating variability in the data, which is in concordance with previous work showing the statistical nature of Jet A ignition. The fuel temperature exceeded the maximum temperatures of 52 and 56.1 °C used in prior work, and significantly lower ignition energies were found, with ignition occurring with a spark energy as low as 0.65 mJ. This is smaller than the MIE found previously for the 5% hydrogen test mixture recommended for aviation safety testing. Fortunately, the recommended test practices of ARP5416 permit richer mixtures and also require validation with a 200 mJ spark. Additionally, the ignition energy density (spark energy divided by the spark length) of kerosene was found to be comparable to the ignition energy densities of the hexane mixture with the lowest MIE. Therefore, the results of the present work indicate that the sensitivity of kerosene must be re-examined, and the variability of spark ignition must also be considered when assessing risk in industry and aviation and designing safety standards.

14/00908 Fuel combustion under asymmetric piston motion: tested results

Hu, J. *et al. Energy*, 2013, 55, 209–215.

This paper presents the measured characteristics of a single piston hydraulic free-piston engine prototype. The detailed results about the piston motion and the fuel combustion are presented. The results show that there is a strong interaction between the piston motion and the fuel combustion in the free-piston engine. The gas force plays a leading role in the innate asymmetric piston motion around top dead centre. The small moving piston inertia makes the asymmetric characteristics more visible. The combustion energy conversion of the single piston hydraulic free-piston engine is fast. Most of the fuel injected burns in 1.0 ms in the pre-mixed combustion phase. Because of the asymmetric characteristics, the mixing-controlled combustion phase in the single piston hydraulic free-piston engine is much shorter than the one in the conventional diesel engine. The short combustion duration decreases the rated power of the free-piston engine. The asymmetric piston motion is unfavourable for the rated power increase of the free-piston engine. The smaller rated power has a negative effect on the free-piston engine application development.

14/00909 Fuel economy optimization of an Atkinson cycle engine using genetic algorithm

Zhao, J. and Xu, M. *Applied Energy*, 2013, 105, 335–348.

An Atkinson cycle engine with geometrical compression ratio of 12.5 has been designed by maximizing fuel economy at full load operating conditions based on the artificial neural network method. However, the Atkinson cycle engine generally operates at part load conditions especially in the middle to high load range. Optimization of the fuel economy for part load is more important in reducing the total fuel consumption. The Atkinson cycle engine applies the load control strategy that combines the intake valve closure timing and electrically throttling control, which has an impact to the fuel economy. Moreover, the exhaust valve opening timing, spark angle (SA) and air–fuel ratio also affect the fuel economy. If calibrating these operating variables over the entire operating range through experiments, the difficulty and cost will become a big issue. A physical model based optimization scheme by coupling MATLAB genetic algorithm (GA) and one-dimensional GT-Power simulation models of the Atkinson cycle engine are proposed. The GT-Power models were improved to accurately simulate the part load conditions, by calibrating parameters of the combustion and heat transfer sub-models using experimental data taken at various speed–load points covering the entire operating range. The fuel economy was optimized based on the part-load calibrated GT-Power models using the Genetic Algorithm. After each speed–load point was optimized, the control maps for the IVC timings, SA, etc. were obtained. Then these numerically optimized control maps were input into the engine control unit as the initial values of the engine calibration, which were further experimentally optimized. The experimental results show that the part-load GT-Power models have sufficient prediction accuracy, with maximal error of 8.5%. After optimized by GA, the fuel economy was greatly improved over the operating range, with the maximal improvement up to 7.67%.

14/00910 Initiated pyrolysis of heavy oil in the presence of near-critical water

Zhu, C.-C. *et al. Fuel Processing Technology*, 2013, 111, 111–117.

The initiated pyrolysis of heavy oil in the presence of near-critical water (near-CW) was investigated with density functional theory (DFT) calculation and experimental characterization. Theoretical calculation indicated the thermodynamic feasibility of forming hydrocarbon radicals in heavy oil with the aid of appropriate radical initiators. By introducing ditertbutyl peroxide (DTBP) into heavy oil, the H-abstraction of H_β atoms distributed mainly in the fractions of saturates, resins, and asphaltenes occurs, forming hydrocarbon radicals located on aliphatic chains with priority. At the temperature of 653 K and water density of $0.30\,g/cm^3$, it was experimentally confirmed that the introduced DTBP was capable of initiating the pyrolysis of heavy oil. After 15 minutes of reaction the pyrolysis products centred toward the fraction of aromatics whose weight proportion in the liquid product increased drastically by *ca.* 25.0 wt%. Meanwhile, only a negligible coke yield of 0.5 wt% was collected.

14/00911 MILD oxy-combustion of gaseous fuels in a laboratory-scale furnace

Li, P. *et al. Combustion and Flame*, 2013, 160, (5), 933–946.

This study investigates the characteristics of moderate or intense low-oxygen dilution (MILD) oxy-combustion in a laboratory-scale furnace. Experiments using natural gas (NG), liquefied petroleum gas (LPG) and ethylene (C_2H_4) are carried out at a firing rate of 13 kW. The furnace temperatures and exhaust emissions are measured for a range of equivalence ratios and external-CO_2 dilution rates. It is observed that MILD combustions occur for the three fuels even when using pure oxygen as oxidant. When diluting oxidant by CO_2 at a fixed rate, the MILD combustion can be established as long as the equivalence ratio (Φ) is sufficiently high. The region of MILD combustion is found to be wider with dilution by CO_2 than by N_2. Notably, also, the operating range of MILD combustion is larger for NG than LPG or C_2H_4 as fuel. Moreover, when $\Phi < 1$, as Φ is increased, the furnace temperature rises slightly but the NO_x emission decreases. This cannot be explained when using the traditional thermal NO_x mechanism. Indeed, using various NO mechanism models, the calculations show very low NO emissions resulting from the thermal, prompt and NNH routes but a much higher value from the N_2O-intermediate route. Namely, only the latter mechanism plays a crucial role in forming NO. Also important is that the NO reburning appears to reduce NO emissions notably and so should not be ignored in the MILD combustion.

14/00912 Novel mixing for ultra-high thermal intensity distributed combustion

Khalil, A. E. E. *et al. Applied Energy*, 2013, 105, 327–334.

Ultra-high thermal intensity colourless distributed combustion has been examined for the aim of achieving near-zero pollutant emission and enhanced performance. A reverse cross-flow configuration has been investigated at thermal intensities in the range of 270–420 MW/m^3-atm with specific focus on the exhaust emissions, distribution of intermediate radical species and flow field within the combustor. Novel simplified geometry is used for easy transition to practical ultra-high thermal intensity gas turbine engine applications. The combustion intensities demonstrated here are significantly higher than that used in current gas turbine engines. Numerical simulations under non-reacting conditions are used to understand the effects of fuel injection in reverse-cross flow configuration. Ultra-low NO emissions were achieved for both the premixed (2 ppm) and non-premixed (5 ppm) mode at thermal intensity of 317 MW/m^3-atm. The CO emission of about 100 ppm and UHC emission of less than 10 ppm, revealed very high combustion efficiency at high heat release intensities. Novel mixing technique is also investigated to further decrease the emissions and enhance reaction distribution. In this case the fuel jet is diluted with a portion of the required air while a portion of the fuel is introduced with the air jet. The equivalence ratio of each of the air jet and fuel jet were kept well outside of the methane air flammability limits, for mitigating the possibility of flame flashback. This approach has demonstrated near zero NO emission, equivalent to that encountered in premixed combustion mode. Numerical simulation and OH* chemiluminescence showed that the mixing and combustion behaviour is dictated by the high momentum of the diluted fuel jet suggesting favourably mixed oxidizer prior to ignition that results in lower NO emissions. Results obtained with different air jet and fuel jet equivalence ratios on the emissions of NO and CO, and OH* chemiluminescence are presented with view to further develop ultra-high thermal intensity zero emission combustors.

14/00913 Numerical investigation of processes in the lignite-fired furnace when simple gray gas and weighted sum of gray gases models are used

Crnomarkovic, N. *et al. International Journal of Heat and Mass Transfer*, 2013, 56, (1–2), 197–205.

Comparison of the numerical investigation results was carried out when the simple gray gas (SGG) and weighted sum of gray gases (WSGG) models are used to model the radiative properties of the gas phase inside the lignite fired furnaces. Comprehensive mathematical model of the tangentially fired furnace by pulverized lignite was made. Gas radiative properties were modelled by the SGG and WSGG models. Radiative heat transfer was modelled by the zonal model. Gas-phase variables and absorbed wall fluxes were compared on the basis of the relative differences that were determined for all control volumes and surface zones. Average relative differences of the gas-phase temperatures were about 1.0%. Average relative differences of the absorbed wall fluxes were from 2.0% to 5.0%. Absorbed wall fluxes determined by the SGG model were bigger than those determined by the WSGG model. Differences of the heat transfer rates of the absorbed radiation through the furnace walls were expressed in percentages of heat transfer rates determined by the SGG model and were similar to the average relative differences of absorbed wall fluxes. Results justify application of the SGG model in comprehensive mathematical models of lignite-fired furnaces.

14/00914 Numerical investigation of pulverized coal jet flame characteristics under different oxy-fuel conditions

Jovanović, R. *et al. International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 654–662.

Pulverized coal combustion in mixture of oxygen and recycled flue gases, known as oxy-fuel combustion, is considered as one of the several possible alternatives to conventional pulverized coal combustion. Switching from conventional pulverized-coal combustion to oxy-fuel combustion brings significant changes in flame properties among which the most important are ignition properties and flame stability. This paper presents the results of experimental and numerical analysis of ignition phenomena under O_2/CO_2 mixtures with different oxygen content. The main focus of the presented paper is to suggest novel ignition sub-model which can describe all possible ignition mechanisms. Proposed ignition sub-model together with large eddy simulation turbulence modelling enables accurate prediction of main flame characteristics: ignition point position, ignition temperature, and flame stability.

14/00915 Preparation and characterization of an activated carbon from a date stones variety by physical activation with carbon dioxide

Sekirifa, M. L. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 155–160.

Activated carbons are commonly used in the treatment of waste water, namely as decontaminating agent of phenolic compounds. This work deals with the preparation of an activated carbon from an abundant local variety of date stones know Ghars. This natural product is largely exploited as a principal nutriment for animal alimentation. Two steps of the activation process are involved in this study, first, a physical treatment by carbon dioxide and second, the characterization of the resulting activated carbon followed by modelization procedure using 4-chlorophenol as test substrate. On the basis of the Brunauer–Emmett–Teller (BET) results, the authors have obtained a specific surface of $604\,m^2/g$ and microspores volumes of $0.29\,cm^3\,g^{-1}$. In addition, the adsorption capacity was about 28.57 mg/g according to Langmuir model. The physical activation method utilized in this task was achieved by using carbon dioxide. Textural characteristics of the resulting activated carbon were carried out by nitrogen adsorption at 77 K along with application of BET equation for determination of surface area. Total volume of pores was determined by αs method. External surface area, micropore area and micropore volume were determined by *t*-plot method. The comparison of raw material, pyrolysed *vis-à-vis* the activated carbon was based on the elemental analysis of the principal elements. The adsorption capacity of the different prepared activated carbons was tested by using 4-chlorophenol as substrate.

14/00916 Pyrolysis kinetic study of Huadian oil shale, spent oil shale and their mixtures by thermogravimetric analysis

Wang, Z. *et al. Fuel Processing Technology*, 2013, 110, 103–108.

The pyrolysis kinetics of Huadian oil shale, spent oil shale obtained from near-critical water extraction experiments and their mixtures were investigated using thermogravimetric analysis. Experiments were performed at four different heating rates of 2, 10, 20 and $50\,K\,min^{-1}$ from ambient temperature to 850 °C under atmospheric pressure and nitrogen flux. The results demonstrated that the thermal decomposition of oil shale, spent oil shale and their mixtures involved three degradation steps. The temperature of the maximum degradation rate

($T_{\max}$) of the oil shale and mixtures shifted toward higher temperature with the increase of heating rate. The extent of interactions during co-pyrolysis was confirmed by comparing the experimental result with the theoretical one. Different thermogravimetric data were analysed by integral method. According to the pyrolysis kinetic analysis, the apparent activation energy of spent oil shale and mixtures was lower than that of oil shale. The values of the obtained apparent activation energy of the mixtures decreased with an increasing spent oil shale fraction because of the decreasing of the macromolecular organic matters which needed much energy during the thermal decomposition. The results suggest that the spent oil shale was helpful for the degradation of oil shale in the mixture.

14/00917 Pyrolysis of orange waste: a thermo-kinetic study

Lopez-Velazquez, M. A. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 170–177.

Thermal and kinetic decomposition of orange waste have been investigated by simultaneous TGA–DSC and TGA–FTIR analysis techniques under nitrogen atmosphere. Thermal profile degradation can be interpreted as the resultant of multiple, parallel and simultaneous reactions, related to: (i) dehydration process for temperatures $\leq$120 °C; (ii) pyrolytic cracking, from 125 to 450 °C, stage where the lignocellulosic components are degraded reaching a maximum the evolved gaseous products and delivery energy; and (iii) to latest stage of lignin degradation, at temperatures $\geq$450 °C. The volatile compounds evolved from 50 to 600 °C were mainly: H_2O, CO_2 and CO, besides of a mixture organic product composed by: carboxylic acids, aldehydes or ketones (C=O), alkanes (C–C), ethers (C–O–C), alcohols (C–O–H), phenolic compounds (C–O) and aliphatic and/or unsaturated aromatic compounds (C=C). Kinetic parameters were calculated by two kinds of model-free kinetics algorithms, Friedman (F) and Kissinger–Akahira–Sunose methods at different heating rates (5, 10 and 15 °C min^{-1}). The results in terms of activation energy show the complex $E_a(\alpha)$ on α dependence, which evidences an multi-step kinetic processes during the pyrolytic cracking of the orange waste.

14/00918 Scale effect of flame instability mechanisms on propagation velocity

Mukaiyama, K. and Kuwana, K. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 387–391.

Blast pressure is a major source of the damage caused by an accidental gas explosion. Its magnitude depends on the thermal expansion rate and hence on the flame propagation velocity. This paper discusses the influence of two flame instability mechanisms, i.e. diffusive-thermal and hydrodynamic instabilities, on flame propagation velocity with an emphasis on their scale effects as the flame continuously increases its size during an explosion. The Sivashinsky equation is numerically solved to simulate flame propagation behaviours. It is found that flame propagation velocity, V_f, is independent of flame size under the influence of diffusive-thermal instability, whereas V_f increases with flame size under the influence of hydrodynamic instability. The latter result is understood as a result of flame's fractal structure. Fractal dimension is determined from the dependency of V_f on flame size, and the obtained fractal dimension is close to the known experimental value.

14/00919 Sustained propagation of ultra-lean methane/air flames with pulsed microwave energy deposition

Michael, J. B. *et al. Combustion and Flame*, 2013, 160, (4), 796–807.

An investigation of pulsed microwave energy addition to laminar methane/air flame fronts is undertaken. Microwave coupling efficiencies of up to 60% are measured in a microwave resonator with very low average power requirements (<30 W). Pulsed microwave energy addition to laminar flame fronts is quantified using power absorption measurements and compared with filtered Rayleigh scattering temperature measurements of a laminar stagnation flame. Relative increases in nitric oxide concentrations are measured using a selective radar REMPI laser technique. For outwardly propagating methane/air flames, short microwave pulse bursts increase the effective flame speed up to 25%. With microwave pulse bursts, results show the ability to sustain deflagration fronts at ultra-lean equivalence ratios of 0.3 (compared to the 0.6 normal lean limit) with microwave energy deposition of 10% of the available thermal energy content of the fuel.

14/00920 Thermal behavior and gaseous emission analysis during co-combustion of ethanol fermentation residue from food waste and coal using TG–FTIR

Su, W. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 79–84.

Thermal characteristics and kinetics of coal and fermentation residue from food waste, including their blends, were evaluated using a non-isothermal thermogravimetric analysis (TGA). The ratio of fermentation residue to the blends by mass was set as 1/6, 2/6, 3/6, 4/6, and 5/6. The sample with 4/6 ratio exhibited the lowest final temperature and highest complex burning index of 2.24×10^{-6} °C^{-3} min^{-2}, which was determined as the optimum ratio. The kinetic analysis demonstrated that the first-order and phase-boundary-controlled reaction models could well describe the burning process with higher correlation index. The gaseous emission analysis by using the coupled Fourier transform infrared (FTIR) measurements was used for HCl, SO_2, CO_2. The results for the sample with ration of 4/6 demonstrated that HCl and SO_2 decreased much more than those other ratio, which indicated that the blends could be regarded as an environmental-friendly fuel.

14/00921 Thermal performance of a micro combustor with heat recirculation

Taywade, U. W. *et al. Fuel Processing Technology*, 2013, 109, 179–188.

In this paper, numerical and experimental investigations in a three-step microcombustor have been carried out to understand the effect of heat recirculation on flame stabilization behaviour with premixed fuel–air mixtures. An external heating cup is used to enhance the heat recirculation. From numerical simulations, it was observed that the extent of heat recirculation is a function of cup dimensions, cup material, and flow velocity and mixture equivalence ratio. Heat recirculation has been observed to significantly enhance the flame stability limits and upper flame stability limits were observed for the range of flow rates investigated during the present work. Stable flames exist for smaller flow rates with a minimum thermal input of ~2.2 W at $\Phi = 0.5$. X-shaped spinning flames exist for intermediate flow rate conditions with and without heat recirculation for a broad range of equivalence ratios. These X-shaped flames rotate around the axis at ~100–150 Hz frequency. The average combustor wall temperature increases with the flow velocity for the stable flame mode and remain mostly uniform and well distributed for the X-shaped spinning flame mode. Heat recirculation helps in increasing the mean wall temperature of the combustor by ~100–400 K.

14/00922 Thermo-acoustic behavior of a swirl stabilized diffusion flame with heterogeneous sensors

Singh, A. V. *et al. Applied Energy*, 2013, 106, 1–16.

Next-generation combustors are expected to be significantly more efficient while reducing pollutants and eliminating carbon emissions. In such combustors, the challenges of local flow, pressure, chemical composition and thermal signatures as well as their interactions require understanding to seek for optimum performance of the system. The current practice of using a single sensor to measure certain parameters at a single location cannot provide sufficient information to achieve desirable and optimum overall performance of the combustor. A high density sensor network with a large number of sensors will be required in future smart combustors to obtain detailed information on the various ongoing processes within the system. As an initial step towards the development of such sensor networks, the effect of mean and fluctuating temperature distribution on the distribution of acoustic sources within the flame has been examined by using a thermocouple and condenser microphone using swirl stabilized diffusion flames. The measurement of high frequency temperature signal allowed observation of characteristic mean and fluctuating temperatures, and thermal stratification characteristics from within the flame. Specifically mean and fluctuating temperatures, integral and micro-thermal time scales have been determined at various spatial locations in the flame. Investigation of the thermal field and their effect on the localization of acoustic sources in the two flames formed at different equivalence ratios has been examined. The thermal characteristics data obtained provided a better insight on the thermal behaviour of co-swirl diffusion flames. Noise spectra for varying air–fuel ratios were determined. Results of time average and fluctuating temperature and sound pressure level spectra showed noise emission in flames to lie near to the regions of high temperature which result in pressure fluctuations within the flame. The results are complemented with three-dimensional computational fluid dynamics simulations that supported the localization of the acoustic sources within the turbulent diffusion flames.

14/00923 Thermogravimetric analysis and kinetics of co-pyrolysis of raw/torrefied wood and coal blends

Lu, K.-M. *et al. Applied Energy*, 2013, 105, 57–65.

The properties of biomass can be improved via torrefaction, and torrefied wood is a fuel with the potential to partially replace coal. In this study, raw *Cryptomeria japonica* (W_{Raw}) is torrefied at 250 (TW_{250}) and 300 °C (TW_{300}) for 1 h, and then mixed with an anthracite coal to undergo co-pyrolysis. A thermogravimetric analyser is used to examine the co-pyrolysis characteristics of fuel blends and five different biomass blending ratios (BBRs) of 100, 75, 50, 25 and 0 wt% are taken into consideration. When W_{Raw}, TW_{250}, and the coal are tested, the pyrolysis is characterized by a three-stage reaction, whereas four-stage thermal degradation is found for TW_{300} and fuel blends. The predictions from the linear superposition of the thermal decomposition of individual fuels fit the experimental data of the fuel blends, suggesting that the interaction or synergistic effect of co-pyrolysis between the raw/torrefied *C. japonica* and the coal is slight. The co-pyrolysis kinetics of the fuel blends is also analysed. The variation of chemical kinetics with decreasing BBR in the second stage is different from that in the third stage. That is, an increase in BBR leads to an increase in the activation energy in the second stage, whereas it causes a decrease in the third stage. This is attributed to that the reactivities of cellulose and lignin in biomass are different from that of coal in the two stages.

Fire safety

14/00924 An electrochemically compatible and flame-retardant electrolyte additive for safe lithium ion batteries

Wu, B. *et al. Journal of Power Sources*, 2013, 227, 106–110.

In this paper, the authors prepared a phosphazenic compound triethoxyphosphazen-N-phosphoryldiethylester (PNP) by a facile method and characterized as a flame-retarding electrolyte additive for lithium ion batteries. The flammability and electrochemical performance of the PNP-containing electrolyte were investigated. The self-extinguishing time (SET) value of 10% PNP in the electrolyte is 40% decreased compared to base electrolyte, implying strong inhabitation to the flammability. The electrochemical performances of MCMB/Li, $LiFePO_4$/Li and $LiMn_2O_4$/Li half-cells in 10% PNP electrolyte exhibit considerable capacity, coulombic efficiency and cycling stability compared to the base electrolyte. Therefore, PNP as flame-retarding additive is a promising candidate combining efficient flame retardancy and good electrochemical performance for safer lithium ion batteries.

14/00925 Global behaviors of enclosure fire and façade flame heights in normal and reduced atmospheric pressures at two altitudes

Hu, L. H. *et al. International Journal of Heat and Mass Transfer*, 2013, 56, (1–2), 119–126.

Enclosure fire safety design and regulations are commonly specified for normal pressure conditions at sea level. There is need however to extend the design requirements for conditions in reduced pressure atmosphere such as city at high altitude, in which the corresponding fundamental behaviour should be clarified first. Experiments are designed and carried out in this work at two different altitudes (Hefei city: 50 m, 1 atm; Lhasa city: 3650 m, 0.64 atm) in a 0.4 m^3 fire enclosure with various window dimensions and an attached 1 m (wide) × 2.2 m (high) façade with and without an opposite facing wall. Gas temperature profiles inside the enclosure and façade flame heights are measured to find out their behavioural changes for these two pressures and to develop global correlations. It is found that, for a given fuel supply rate the gas temperature inside the enclosure is lower while the outside flame is higher in the reduced pressure atmosphere, owing to the lower fuel consumption inside the enclosure and air entrainment into the flame. The flame height (without a facing wall) normalized by a characteristic window length scale ℓ_1 can be well correlated with the dimensionless excess heat release rate, but being a bit higher due to lower entrainment or larger fluctuations at lower pressure, but can be accounted for globally by a correction factor of 0.8. In addition, the characteristic length scale ℓ_3 representing the horizontal projection of the flame is higher, and thus, the critical distance of the facing wall from the enclosure, at which interaction of the façade flame and the opposite facing wall starts, is larger at lower pressure. The relative higher façade flame height and the larger critical façade-to-facing-wall distance suggest that hazards of enclosure facade fires at low pressure (high altitude) are higher and it need more conservative regulations than those at standard pressure. By accounting for their behavioural changes, global models have been correlated for gas temperature inside the enclosure as well as façade flame height without and with an opposite facing wall applicable for these two atmospheric pressures. The present results and global correlations in both normal and reduced pressure atmosphere provide fundaments of guideline for regulations extension to high altitude and are a significant supplement and improvement over previous results in literatures.

14/00926 Influence of longitudinal wind on natural ventilation with vertical shaft in a road tunnel fire

Zhong, W. *et al. International Journal of Heat and Mass Transfer*, 2013, 57, (2), 671–678.

The influence of longitudinal wind on natural ventilation with vertical shaft in a road tunnel fire was investigated numerically by large eddy simulation. The smoke flow characteristics of a road tunnel fire under the combined function of longitudinal wind and stack effect of shaft were analysed. Results show that the stack effect, plug-holing and boundary layer separation are the dominating factors on the natural ventilation performance. Plug-holing occurs at small longitudinal velocity and causes the reduction of exhaust effect. At high longitudinal velocity, the driving force of smoke exhausting is weak and obvious boundary layer separation occurs, resulting in a poor exhaust capacity. There is a critical value of longitudinal wind velocity, in which a better smoke exhausting effect can be obtained.

14/00927 Instantaneous phosphor thermometry applicable to walls exposed to flames

Someya, S. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 224–231.

It is important to be able to measure the temperature distribution of walls that are exposed to high temperatures, such as fire walls and internal combustion engines, in order to improve their performance. However, only a few studies have quantitatively visualized the two-dimensional temperature distribution of walls exposed to flames. Phosphor thermometry is a key approach to measuring the temperature distributions of walls, since phosphorescence lifetimes and spectra vary over a wide temperature range. In this study, the luminescence properties of the phosphor, $Y_2O_2S:EuSm$, were investigated. Although the temperature sensitivity of its spectral shape was only 0.008%/°C in the range 50–210 °C, that of its luminescence lifetime was 0.78%/°C. Lifetime-based phosphor thermometry was performed using a simple experimental setup consisting of a non-intensified high-speed CMOS camera, a pulsed UV laser, and a phosphor coated with a thin metal film. It was found that the excitation power had little effect on the phosphor lifetime and that the metal film did not affect the phosphorescence lifetime. The temperature measurement uncertainty was determined to be ±4.4 °C from measurements of uniform temperature fields. Instantaneous wall temperature measurements were demonstrated during flame combustion in a rapid compression expansion machine. The measured temperatures agreed with those measured by a thin thermocouple. The proposed system is capable of measuring the instantaneous wall temperature even in a combustion chamber.

14/00928 Large eddy simulations of wake-stabilised flares

Lawal, M. S. *et al. Fuel Processing Technology*, 2013, 112, 35–47.

This paper investigates the potential benefits, as well as limitations, of using the large eddy simulation (LES) technique to predict the combustion efficiency, emissions and temperatures of wake-stabilized flares. LES calculations have been performed for two jet-to-cross-flow momentum flux ratios, with the results being compared with experimental data, where available, and with predictions of a closed Reynolds-averaged Navier–Stokes (RANS) model using a second-moment turbulence closure. The flame fragmentation and the secondary flame zone attached to the release pipe at high jet-to-cross-flow momentum flux ratios, and their influence on the evolution of the counter-rotating vortex pair found in such flames, are discussed in detail, with realistic predictions being produced by the LES. The global mixing characteristics and the combustion efficiency of such flames are also compared with available data with reasonable agreement found. In all cases, LES predictions are found to be superior to equivalent RANS results, although the extra computational effort required in predicting species concentrations and flare efficiencies, in particular, may not be warranted.

14/00929 Methane–air detonation experiments at NIOSH Lake Lynn Laboratory

Zipf Jr., R. K. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 295–301.

The methane–air detonation experiments are performed to characterize high pressure explosion processes that may occur in sealed areas of underground coal mines. The detonation tube used for these studies is 73 m long, 105 cm internal diameter and closed at one end. The test gas is 97.5% methane with about 1.5% ethane, and the methane–air test mixtures varied between 4% and 19% methane by volume. Detonations were successfully initiated for mixtures containing between 5.3% and 15.5% methane. The detonations propagated with an average velocity between 1512 and 1863 m/s. Average overpressures recorded behind the first shock pressure peak varied between 1.2 and 1.7 MPa. The measured detonation velocities and pressures are close to their corresponding theoretical Chapman–Jouguet (CJ) detonation velocity (D_{CJ}) and detonation pressure (P_{CJ}). Outside of these detonability limits, failed detonations produced decaying detached shocks and flames propagating with velocities of approximately $\frac{1}{2}D_{CJ}$. Cell patterns on smokefoils during detonations were very irregular and showed secondary cell structures inside primary cells. The measured width of primary cells varied between 20 cm near the stoichiometry and 105 cm (tube diameter) near the limits. The largest detonation cell (105 cm wide and 170 cm long) was recorded for the mixture containing 15.3% methane.

14/00930 Modeling the impact of fire spread on an electrical distribution network

Bagchi, A. *et al. Electric Power Systems Research*, 2013, 100, 15–24.

This paper proposes a methodology for studying the effects of fire on the electrical distribution network of a city. The study leverages the model of urban fire spread software application to simulate an urban fire along with its subsequent suppression, and performs extensive simulations of different fire spread scenarios on a synthetic city named Micropolis. The damage caused to the electrical infrastructure for a given fire spread scenario is quantified using a parameter called the load loss damage index (LLDI). Since most distribution networks contain normally open switches for reliability purposes, this paper uses a simple graph theoretic approach for rerouting power across isolated sections of the network which are damaged by fire. The approach attempts to minimize the voltage drops at the most downstream customer points by rerouting power along paths of minimum impedance. Important conclusions drawn from the analysis of the LLDI values generated from extensive simulation runs are presented.

14/00931 On preheating and dilution effects in non-premixed jet flame stabilization

Lamige, S. *et al. Combustion and Flame*, 2013, 160, (6), 1102–1111.

The impact of preheating and dilution on methane/air non-premixed flame stability are studied experimentally. Six preheating levels are considered for initial reactant temperature between 295 and 850 K in a round jet configuration. Four diluent gases are added on the air-side, either CO_2, N_2, Ar or a $(CO_2 + Ar)$ mixture having the same molar heat capacity as N_2. For undiluted flames, jet transition velocities between attached and lifted states are investigated depending on initial reactant temperature. The hysteresis zone defined by these stability limits is shifted towards higher jet velocities with preheating. Whereas jet and coflow temperatures were identical in similar previous experiments, the present work allows examination of the thermal effects from either fuel or oxidizer streams. Flame stability is described based on the propagative aspects of the flame leading-edge, by analogy with the temperature dependency of the laminar burning velocity of a stoichiometric mixture. Results show that the jet temperature has a major influence on the lifting of an attached flame, whereas the coflow temperature remains important for the reattachment of a lifted flame. In addition, flame stability experiments have been performed at high levels of both preheating and dilution. Stability maps of critical dilution ratios at lifting have been obtained with preheating. It appears that the ability of a diluent to break flame stability keeps the same relative order as at ambient temperature. It is even enhanced with preheating because higher temperature widens the gap between diluent molar heat capacities Cp. The Cp approach is however not sufficient to interpret the temperature dependency of the relative influence of the different dilution effects. Furthermore, the role played by the jet flow regime on attached flame stability in dilution-induced lifting experiments is highlighted when dilution is coupled with preheating.

14/00932 Production of fire extinguishing mixture by solid propellant propulsion

Karpov, A. I. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 338–343.

The behaviour of fire suppression by water mist spray has been studied by using the experimental setup which employs the double-based solid propellant gas generator for water mist production. The burning products of solid fuel form a supersonic flow injected through the nozzle into the diffuser chamber having input for the water component ejected from the storage. High values of temperature and pressure at stagnation point impart the substantial kinetic energy to the flow, which provides the atomization of water droplets into mist spray. Since the water evaporation occurs already in the diffuser chamber due to the high temperature of input gas flow, the droplet size is gradually decreases to the lower limit value that could ever exist. The presence of vapour phase enlarges the volume of fire extinguishing jet allowing it to operate as a flooding agent (along with the effect of heat consumption due to water evaporation) at the very beginning of fire suppression process, much before the water droplets evaporation by the flame itself. The proposed technique of the water mist production has showed noticeable fire suppression capability through the series of testing application to the gasoline and wood model fire sources.

14/00933 Simple method for predicting pressure behavior during gas explosions in confined spaces considering flame instabilities

Nishimura, I. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (2), 351–354.

It is indispensable to predict the pressure behaviour caused by gas explosions for the safety management against accidental gas explosions. In this study, a simple method for predicting the pressure behaviour during gas deflagrations in confined spaces was examined. Previously the pressure behaviour was calculated analytically assuming laminar flame propagation. However, the results of this method often provide underestimation compared with experimental data. It was known the underestimation intensifies as the scale of explosion spaces becomes larger. On the large-scale gas deflagration, flame instability (especially hydrodynamic instability) might be more effective and wrinkles appeared on the flame front. Then, the flame surface area was increased and the propagating flame was gradually accelerated. The ordinary prediction methods led to the underestimation because the propagating flame was assumed to be laminar. This study considered the effect of flame wrinkles caused by flame instabilities. By regarding the flame front as a fractal structure, the flame surface area could be modified. Because a flame surface starts to be wrinkled on a certain flame radius, proper determination of the critical flame radius provided accurate prediction of pressure behaviour on a large-scale deflagration. In addition, correction of the K_G value in a large vessel was discussed.

14/00934 Time–space adaptive numerical methods for the simulation of combustion fronts

Duarte, M. *et al. Combustion and Flame*, 2013, 160, (6), 1083–1101.

This paper presents a new computational strategy for the simulation of combustion fronts based on adaptive time operator splitting and spatial multi-resolution. High-order and dedicated one-step solvers compose the splitting scheme for the reaction, diffusion, and convection subproblems, to independently cope with their inherent numerical difficulties and to properly solve the corresponding temporal scales. Adaptive and thus highly compressed spatial representations for localized fronts originating from multi-resolution analysis result in important reductions of memory usage, and hence numerical simulations with sufficiently fine spatial resolution can be performed with standard computational resources. The computational efficiency is further enhanced by splitting time steps established beyond standard stability constraints associated to mesh size or stiff source time scales. The splitting time steps are chosen according to a dynamic splitting technique relying on solid mathematical foundations, which ensures error control of the time integration and successfully discriminates time-varying multi-scale physics. For a given semi-discretized problem, the solution scheme provides dynamic accuracy estimates that reflect the quality of numerical results in terms of numerical errors of integration and compressed spatial representations, for general multi-dimensional problems modelled by stiff PDEs. The strategy is efficiently applied to simulate the propagation of laminar premixed flames interacting with vortex structures, as well as various configurations of self-ignition processes of diffusion flames in similar vortical hydrodynamics fields. A detailed study of the error control is provided and shows the potential of the approach. It yields large gains in CPU time, while consistently describing a broad spectrum of space and time scales as well as different physical scenarios.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

14/00935 Achieving energy self-sufficiency by integrating renewables into companies' supply networks

Kiraly, A. *et al. Energy*, 2013, 55, 46–57.

The aim of this contribution was to present the integration of renewables into companies' supply-networks at regional level in order to maximize the self-sufficiencies of their energy supplies. This concerns companies' activities from the use of natural resources to supplying their final products to the customers being interlinked with their regional networks. A mixed-integer linear programming (MILP) model has been developed for the synthesis of companies' supply-networks utilizing different types of renewables as sources for the companies' energy supplies, and embedded into the MILP model, previously developed by authors, for the synthesis of regional biomass production and supply networks. The integrated synthesis model was applied to an existing large-scale meat company. The potential renewable energy sources, which are located within companies surrounding region are solar, biomass, organic and animal wastes. The result indicates that by sufficient integration of renewables into companies' supply networks, profitable and yet energy self-sufficient solutions can be obtained.

14/00936 An overview of novel technologies to valorise coke oven gas surplus

Bermúdez, J. M. *et al. Fuel Processing Technology*, 2013, 110, 150–159.

The steelmaking industry is the largest energy-consuming manufacturing sector in the world and is responsible for 5–7% of anthropogenic CO_2 emissions. It is therefore necessary to increase energy efficiency and reduce greenhouse gases emissions in these industries. Coke oven gas (COG), a by-product of coking plants, is one of the key ways to achieve these goals. COG, which is used as fuel in different processes of the steelmaking plants, is a hydrogen-rich gas with a high energetic potential. However, there is a significant surplus that usually is burnt away in torches, and even directly emitted into the air. With the aim of tackling this wasting of resources and energy inefficiency, several alternatives have been proposed during recent years. In the present work, these alternatives are reviewed and their main advantages and drawbacks are discussed.

14/00937 Classification and optimization of potentially runaway processes using topology tools

Copelli, S. *et al. Computers & Chemical Engineering*, 2013, 56, 114–127.

Fast and strongly exothermic reactions can exhibit a well-known phenomenon called 'thermal runaway'. To identify high productivity and safe conditions for these reactions, with particular reference to industrial semibatch processes carried out using both isothermal and isoperibolic temperature control mode, a dedicated classification/optimization software has been implemented. This software is able to both classify a set of operating parameters from the thermal stability viewpoint and identify the optimum reacting/synthesis conditions using a topological criterion that binds the so-called 'QFS region', where reactants accumulation is low and all the heat released is readily removed by the cooling equipment. During the search for system optimum a number of safety and quality constraints can be taken into account. The software reliability, in terms of both classification and optimization ability, has been tested using both laboratory and industrial scale experimental data. Obtained results confirm a good agreement between theoretical predictions and experimental evidence.

14/00938 Decentralized plantwide control strategy for large-scale processes. Case study: pulp mill benchmark problem

Luppi, P. A. *et al. Computers & Chemical Engineering*, 2013, 52, 272–285.

The plantwide control (PWC) complexity increases for highly integrated and large-scale chemical processes. This work presents a novel framework for decentralized PWC which includes: (i) the selection of the controlled variables (CVs), (ii) the pairing between the manipulated variables (MVs) and the CVs and (iii) the determination of the controller algorithms as well as their tuning parameters for closed-loop operation. The proposal is to solve the steps (i) and (ii) simultaneously, driving the selection of the most effective PWC structure from a Pareto optimal set. Here, algorithms based only on steady-state information are considered to give a systematic procedure which tries to minimize the use of heuristic considerations. Genetic algorithms (GA) and the Hungarian algorithm (HA) are used here because they provide a good trade-off between computational effort and acceptable results. The proposed methodology is completely tested in a pulp mill benchmark and compared with a previous one.

14/00939 Dissipativity analysis for networks of process systems

Hioe, D. *et al. Computers & Chemical Engineering*, 2013, 50, 207–219.

The paper presents stability and stabilizability analysis for plant-wide chemical processes. The process is modelled as a network of process systems with multiple recycle streams and energy integration. One of the key problems addressed in the paper is how to determine dissipativity properties of the process network from the dissipativity properties of the individual process systems and the topology of the network. The results in the paper extend the dissipativity analysis based on thermodynamics for individual processes to dissipativity-based conditions (storage functions and supply rates) suitable for process network analysis. The new storage and supply functions are based on balance equations represented in terms of temperatures and compositions rather than internal energy and chemical potentials. This makes the theory easier to apply to typical chemical process model systems. A simple example is provided to illustrate the application of the theory.

14/00940 Economic analysis of alternatives for optimizing energy use in manufacturing companies

Méndez-Piñero, M. I. and Colón-Vázquez, M. *Energy Economics*, 2013, 40, 146–154.

The manufacturing companies are one of the main consumers of energy. The increment in global warming and the instability in the petroleum oil market have motivated companies to find alternatives to reduce energy use. In the academic literature several researchers have demonstrated that optimization models can be successfully used to reduce energy use. This research presents the use of an optimization model to identify feasible economic alternatives to reduce energy use. The economic analysis methods used were the payback and the internal rate of return. The optimization model developed in this research was applied and validated using an electronic manufacturing company case study. The results demonstrate that the main variables affecting the economic feasibility of the alternatives are the economic analysis method and the initial implementation costs. Several scenarios were analysed and the best results show that the manufacturing company could save up to $78,000 in 3 years if the recommendations based on the optimization model results are implemented.

14/00941 Effect of surface energy on the transition from fixed to bubbling gas-fluidised beds

Yang, F. *et al. Chemical Engineering Science*, 2013, 90, 119–129.

Two-dimensional discrete element method/computational fluid dynamics simulations have been performed in order to examine the effect of surface energy on the transitional behaviour from fixed bed to bubbling bed for Geldart type A particles. The results of the simulations presented in the paper show that any effect of surface energy on the magnitude of U_{mf} is not due to increasing bed resistance as a result of increasing the interparticle bond strength. It is demonstrated that U_{mf} corresponds to a deterministic (isostatic) state that is in effect the initiation of the transition from solid-like to fluid-like behaviour. It is also shown that the so-called 'homogeneous expansion' regime is not in fact homogeneous. This is because the system, when $U > U_{mf}$, consists of agglomerates. Consequently, the idea that bed expansion is due to the 'elasticity' of the bed is not tenable. In order to break up the agglomerates and create a fully fluidized bed that will allow bubbling to occur, higher superficial gas velocities are required for higher values of surface energy. Once the bed is fully fluidized and bubbling occurs the effect of surface energy becomes insignificant.

14/00942 Estimates of inter-fuel substitution possibilities in Chinese chemical industry

Lin, B. and Wesseh Jr., P. K. *Energy Economics*, 2013, 40, 560–568.

The chemical sector is a key driver of China's remarkable growth record and accounts for about 10% of the country's gross domestic product. This has made the industry energy-intensive and consequently a major contributor to greenhouse gas emissions (GHG) and other pollutants. This study has attempted to investigate the potential for inter-fuel substitution between coal, oil, natural gas and electricity in Chinese chemical sector by employing a translog production and cost function. Ridge regression procedure was adopted to estimate the parameters of the function. Estimation results show that all energy inputs are substitutes. In addition, the study produces evidence that the significant role of coal in the Chinese chemical fuel mix converges over time, albeit slowly. These results suggest that price-based policies, coupled with capital subsidy programs can be adopted to redirect technology use towards cleaner energy sources like electricity and natural gas; hence, retaining the ability to fuel the chemical sector, while also mitigating GHG emissions. Notwithstanding, one must understand that the extent to which substituting electricity for coal will be effective depends on the extent to which coal or oil is used in generating electricity. The findings of this study provide general insights and underscore the importance of Chinese government policies that focus on installed capacity of renewable electricity, energy intensity targets as well as merger of enterprises.

14/00943 Heat integration options based on pinch and exergy analyses of a thermosolar and heat pump in a fish tinning industrial process

Quijera, J. A. *et al. Energy*, 2013, 55, 23–37.

Thermosolar technology is being inserted gradually in industrial activities. In order to reach high energy efficiency, thermosolars can be linked to heat pump technology, combining more efficient conventional and renewable energy support for processes. Their integration in complex processes can be improved systematically through well-established analytical tools, like pinch and exergy analyses. This work presents a methodological procedure for the analysis of different options of heat integration of a solar thermal and heat pump technologies in a tuna fish tinning process. The plant is located in a climatic zone where diffuse irradiation contributes more energy to the process than beam irradiation does. Pinch and exergy analyses are applied in the context of a low and middle temperatures, where the process demands big amounts of hot water and middle pressure steam. In order to recover internal heat, pinch analysis allows to understand the complexity of the heat exchange network of the process and to define thermal tendency objectives for energy optimization. Exergy analysis quantifies the variation that the quality of energy undergoes while it is used in the process according to the different way of integration. Both analytical tools, in combination with economic variables, provide a powerful methodological procedure finding the most favourable heat integration and, by this, they help in the technological decision making and in the design phase.

14/00944 Intensification of viscous fluid mixing in eccentric stirred tank systems

Zhang, M. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 66, 36–43.

The mixing process of highly viscous liquids in a small stirred tank for high throughput experimentation (HTE) apparatus was investigated using a visualization approach, i.e. the planar laser-induced fluorescence (PLIF) technique. Segregated regions were detected despite a long period of agitation, indicating that the mixing homogeneity can be hardly attained for the mixing of highly viscous liquid. Based on the image analysis of PLIF results, the authors defined a desegregating time to quantify the mixing process of viscous liquids and to compare the mixing performances under different operating conditions. Eccentric agitation proved to be an efficient way to intensify the mixing of viscous liquid for the fact of significantly reduced desegregating time under the same stirring rate.

14/00945 Market equilibrium in the presence of green consumers and responsible firms: a comparative statics analysis

Doni, N. and Ricchiuti, G. *Resource and Energy Economics*, 2013, 35, (3), 380–395.

This paper analyses how the interaction between green consumers and responsible firms affects the market equilibrium. The main result is that a higher degree of responsibility of consumers and/or firms may both increase and decrease the total abatement and the social welfare. In general an increment in the degree of corporate social responsibility (CSR) of a firm entails an increase of its total clean-up and a reduction of the aggregate abatement of its rival. When the rival firm has a high degree of CSR this second effect is stronger than the first and total abatement falls down. At the same time, when the degree of consciousness of consumers and/or firms is very high, responsible firms overprovide environmental quality: in such case a further increment in the level of social responsibility of a market actor may trigger an increase of firms' total clean-up but a reduction in social welfare.

14/00946 Optimal integration of organic Rankine cycles with industrial processes

Hipólito-Valencia, B. J. *et al. Energy Conversion and Management*, 2013, 73, 285–302.

This paper presents a procedure for simultaneously handling the problem of optimal integration of regenerative organic Rankine cycles (ORCs) with overall processes. ORCs may allow the recovery of an important fraction of the low-temperature process excess heat (i.e. waste heat from industrial processes) in the form of mechanical energy. An integrated stagewise superstructure is proposed for representing the interconnections and interactions between the heat exchanger network and the ORC for fixed data of process streams. Based on the integrated superstructure, the optimization problem is formulated as a mixed integer non-linear programming problem to simultaneously account for the capital and operating costs including the revenue from the sale of the shaft power produced by the integrated system. The application of this method is illustrated with three example problems. Results show that the proposed procedure provides significantly better results than an earlier developed method for discovering optimal integrated systems using a sequential approach, due to the fact that it accounts simultaneously for the tradeoffs between the capital and operating costs as well as the sale of the produced energy. Also, the proposed method is an improvement over the previously reported methods for solving the synthesis problem of heat exchanger networks without the option of integration with an ORC (i.e. stand-alone heat exchanger networks).

14/00947 Optimisation-based design method for membrane-assisted separation processes

Koch, K. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 2–15.

This paper presents a design method for membrane-assisted separation processes based on the concept of process superstructure optimization, which should be applied to the separation of azeotropic mixtures. The main features of the proposed method are as follows: (i) detailed rate-based modelling of all unit operations; (ii) experimental model identification for membrane separation; (iii) application of an evolutionary algorithm. This method allows the simultaneous determination of optimal process configuration, equipment design and operating conditions for membrane-assisted separation processes. A case study for the separation of a ternary mixture of acetone, isopropyl alcohol and water in a hybrid pervaporation-distillation process is presented using the optimization-based design method. Detailed rate-based models for the unit operations involved were implemented in a generic process model and necessary membrane model parameters were determined experimentally in a laboratory-scale device for the hydrophilic polymeric membrane Pervap^{TM} 2201D from Sulzer Chemtech. After the identification of an appropriate process superstructure, the process configuration, dimensions of equipment and operating conditions required for the optimal hybrid pervaporation-distillation process were determined simultaneously. The optimization criterion was the cost for purifying one ton of acetone. The results show that the developed method can be applied successfully for this complex mixed-integer non-linear optimization problem.

14/00948 Performance study of fuel oil additives in real power plant operating conditions

Prelec, Z. *et al. Fuel Processing Technology*, 2013, 110, 176–183.

The aim of the study described in this article is to determine the effectiveness of fuel oil additives used in heavy duty conditions. The research has been conducted during real operating conditions of a steam boiler, belonging to a 320 MW power plant, in order to reveal fuel additive effectiveness in controlling flue gas emissions, plant availability, maintenance costs and operating efficiency. Portable instruments have been used to measure emission of pollutants during the testing period simultaneously with the installed monitoring equipment for continuous measurements. Adequate methods have been chosen and used to determine the corrosion rate, deposit grow-up, SO_2 to SO_3 conversion and the steam boiler efficiency. The results are presented graphically to compare effects of tested additives during four phases of examination in relation to the type of additive, steam boiler load and excess air for combustion.

14/00949 Simulation study on a reactive distillation process of methyl acetate hydrolysis intensified by reaction of methanol dehydration

Tong, L. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 111–119.

Methyl acetate (MeOAc) recovery from the polyvinyl alcohol (PVA) production is a difficult and heavy energy consuming process. In this work, a reactive distillation (RD) process of MeOAc hydrolysis intensified by methanol (MeOH) dehydration, as an auxiliary reaction, was proposed. Two different feeds with the mole ratio of MeOAc to MeOH at 1 : 1 and 1 : 9 were studied, and the effect of the operating pressure, the feed location and the reflux ratio on the RD column was analysed. The simulations of reactive distillation were performed using a three-phase non-equilibrium model implemented by gPROMS. As the limit of the reaction rate of MeOH dehydration, it is impossible to get 100% conversion of MeOAc and MeOH by a single RD column. Therefore, two novel processes for recovery of methyl acetate in PVA production were developed. The simulation results show that the high purity of dimethyl ether (DME) could be achieved with a complete conversion of MeOAc, and a large amount of energy demand and equipment costs can be reduced.

14/00950 STRUCTese® – energy efficiency management for the process industry

Drumm, C. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 99–110.

Besides the development of future energy concepts energy efficiency today offers a powerful and cost-effective tool for achieving a sustainable energy future. Successful reduction of energy consumption and emissions requires a systematic approach. Thereby, energy management systems help to successfully reduce the energy consumption and CO_2e emissions. In the present work, a structured efficiency system for energy (STRUCTese®) was developed, which allows the detailed measurement and tracking of energy efficiency in contrast to measuring mere energy consumption. STRUCTese® provides full transparency about the *status quo* and the further improvement potential up to the limit of best available technology. Results for a real plant are presented which show the benefit of such a transparent visualization of energy efficiency. The work shows how the difficult task to measure and improve energy efficiency in a chemical plant can be mastered.

14/00951 Tracking industrial energy efficiency trends using index decomposition analysis

Ang, B. W. and Xu, X. Y. *Energy Economics*, 2013, 40, 1014–1021.

Index decomposition analysis (IDA) has been widely used to track economy-wide and sectoral energy efficiency trends. An integral part of this application is identifying the drivers of energy use for the energy consuming sector studied. In the case of industry, a monetary activity indicator such as value added is often taken as the driver. With the availability of physical production data for some industry subsectors, such as in tonnes or cubic metres, effort has been made by researchers to incorporate physical activity indicators in order to produce results that can better capture energy efficiency trends. The authors review and consolidate two different approaches to incorporating physical activity indicators in industrial energy studies using IDA. Based on their underlying concept, they are referred to as the intensity refactorization (IR) approach and the activity revaluation (AR) approach. The authors refine the AR approach, and compare the AR, IR, and the conventional monetary-based IDA approaches. Numerical examples and recommendations are presented.

10 SPACE HEATING AND COOLING/HEAT PUMPS

14/00952 A numerical and experimental analysis of the air vent management and heat storage characteristics of a trombe wall

Liu, Y. *et al. Solar Energy*, 2013, 91, 1–10.

The optimum opening and closing modes in the management of air vents were found by testing and analysing thermal performance parameters of a trombe wall installation. The parameters considered included air vent velocity, air vent temperature, the temperature distribution of air layer and indoor air temperature. The temperature and velocity distribution of the air layer were obtained by numerical calculation, together with experimental data including the heat storage and release characteristics and the influencing factors of the trombe wall. The research results show: the optimum time to open the air vent of the trombe wall is 2–3 h after sunrise with closure 1 h before sunset. On the condition of optimum air vent management mode, surface and average temperature of heat storage wall computer simulations were run with computational fluid dynamics to analyse the heat storage and release performance of trombe wall. From this, the heat storage capacity of the trombe wall reaches its maximum value at 4pm, its minimum value at 7–8am. These research results provide a reference base for the optimization of design and the operational management of a passive solar house with trombe wall.

14/00953 A nano-graphite/paraffin phase change material with high thermal conductivity

Li, M. *Applied Energy*, 2013, 106, 25–30.

Nano-graphite (NG)/paraffin composites were prepared as composite phase change materials. NG has the function of improving the thermal conductivity of the composite. The microstructure and thermal properties of the materials were examined with environmental scanning electron microscopy and differential scanning calorimetry. The results indicated that the NG layers were randomly dispersed in the paraffin, and the thermal conductivity increased gradually with the content of NG. Thermal conductivity of the material containing 10% NG were 0.9362 W/m K.

14/00954 A review of transcritical carbon dioxide heat pump and refrigeration cycles

Ma, Y. *et al. Energy*, 2013, 55, 156–172.

As a natural refrigerant, carbon dioxide is safe, economic and environmentally sustainable which can be used in heat pump and refrigeration systems especially in transcritical cycles. From the early 1990s, in which the carbon dioxide transcritical cycle began, theoretical and experimental researches, as well as commercial system development, has improved to make the transcritical system performance to a level similar to that of conventional heat pump systems. This paper presents an overview of transcritical carbon dioxide heat pump and refrigeration systems. The paper introduces a summary of the history and main application of carbon dioxide's use as a refrigerant firstly. Secondly, the properties of supercritical pure carbon dioxide and that containing polyalkylene glycol lubricants are analysed and reviewed. The paper begins with an analysis of some special characteristics of the basic carbon dioxide transcritical cycle such as the optimum system high pressure and so on, and then follows with a performance analysis and comparison of several novel transcritical cycles. The study finally presents a review of research on transcritical carbon dioxide heat pump systems covering the main components and research hotspots, such as heat transfer and expander.

14/00955 A systematic approach for synthesizing combined mass and heat exchange networks

Liu, L. *et al. Computers & Chemical Engineering*, 2013, 53, 1–13.

Mass and heat are very important resources in the process industry. Numerous approaches have been proposed for the optimization of either mass or heat exchange networks. Since the process usage of mass and heat is typically intertwined, it is important to account for such interactions. The objective of this paper is to introduce a systematic method for the simultaneous synthesis of combined mass- and heat-exchange networks (CMAHENs). The proposed method is based on a novel approach that incorporates the mass pinch technology (MPT) for mass exchange networks (MENs) synthesis and the pseudo-T-H diagram approach (PTHDA) for the heat exchange networks (HENs) synthesis. New bypass streams are included in the structural representation of the problem to expand the search space. A combined optimization approach is applied to minimize the total annualized cost of the CMAHEN. Finally, two cases are solved to illustrate the application of the proposed method.

14/00956 An experimental evaluation of the living wall system in hot and humid climate

Chen, Q. *et al. Energy and Buildings*, 2013, 61, 298–307.

This research aims to identify the microclimate of the living wall system (LWS) in a hot and humid climate and to examine how ventilation and different wall-vegetation distances (w–v–d) affect the thermal performance of the LWS. Two identical thermal labs are constructed with adjustable LWS installed on their west-facing walls in Wuhan, China. Three series of experiments were carried out. Results show that the LWS has a notable cooling effect to the wall surface and the indoor space. The microclimate created by the LWS features in a cool layer of air with identical mean relative humidity as the ambient air. Instead of gaining heat, the exterior wall surface is losing heat to the microclimate all day, where the LWS is the cooling instrument that removes heat by radiative heat exchange. The LWS with a sealed air layer performs better in cooling the wall surface than the LWS with a naturally ventilated air layer. Lastly, three comparison experiments tested the LWS with different w–v–d: 30, 200, 400 and 600 mm. Results show that the smaller distance has better cooling effect but higher relative humidity in the air layer.

14/00957 An innovative borehole heat exchanger configuration with improved heat transfer

Focaccia, S. and Tinti, F. *Geothermics*, 2013, 48, 93–100.

This paper presents an innovative borehole heat exchanger (BHE) configuration in which the vertical probes are immersed in an artificial fluid, contained in a case separated from the ground by the usual filling material. This system leads to an increased heat transfer within the borehole due to the onset of induced natural convection in the annulus between the protection system and the vertical probes. The related thermal resistance and capacity models are presented for grouting filled conditions.

14/00958 Analysis and sizing of thermal energy storage in combined heating, cooling and power plants for buildings

Martínez-Lera, S. *et al. Applied Energy*, 2013, 106, 127–142.

Thermal energy storage (TES) can lead to significant energy savings and economic benefits in combined heating, cooling and power plants (CHCPs) for buildings in the tertiary sector. However, their complex interactions with the rest of the CHCP system make their adequate sizing difficult without using extensive and detailed simulations. The authors have developed a new method to evaluate the thermal contribution of TES based on simple procedures. Comparisons with detailed simulations for a range of situations confirm the ability of this method to predict the effect of TES on CHCP systems with good approximation, as well as to find the optimal size in a relatively simple manner and with few required data. The case studies show a strong dependence of the TES contribution on the demands profile and the operation strategy. However, adequately sized TES are proven to bring relevant energy savings as well as economic profit to CHCPs. In this paper, sizing procedures are provided to find the optimal volume both in terms of thermodynamic efficiency and of economic profit.

14/00959 Characterization and qualification of advanced insulators for fusion magnets

Humer, K. *et al. Fusion Engineering and Design*, 2013, 88, (5), 350–360.

Intensive research over the past decades demonstrated that the mechanical material performance of epoxy based glass fibre reinforced plastics, which are normally used by industry as insulating materials in magnet technology, degrades dramatically on irradiation to fast neutron fluences above $1 \times 10^{22}\,\mathrm{m}^{-2}$ ($E > 0.1\,\mathrm{MeV}$) which have to be expected in large fusion devices like the International Thermonuclear Experimental Reactor (ITER). This triggered an insulation development program based on cyanate ester (CE) and blends of CE and epoxies, which are not affected up to twice this fluence level, and therefore appropriate for large fusion magnets like the ITER toroidal field coils. Together with several suppliers resin mixtures with very low viscosity over many hours were developed, which renders them suitable for the impregnation of very large volumes. This paper reports on a qualification programme carried out during the past few years to characterize suitable materials, i.e. various boron-free R-glass fibre reinforcements interleaved with polyimide foils embedded in CE/epoxy blends containing 40% of CE, a repair resin, a conductor insulation, and various polyimide/glass fibre bonded tapes. The mechanical properties were assessed at 77 K in tension and in the interlaminar shear mode under static and dynamic load conditions prior to and after reactor irradiation at ~340 K to neutron fluences of up to $2 \times 10^{22}\,m^{-2}$ ($E > 0.1\,MeV$), i.e. twice the ITER design fluence. The results confirmed that a sustainable solution has become available for this critical magnet component of the ITER.

14/00960 Concrete roof with cylindrical holes containing PCM to reduce the heat gain

Alqallaf, H. J. and Alawadhi, E. M. *Energy and Buildings*, 2013, 61, 73–80.

This paper presents a thermal analysis of a building concrete roof with vertical cylindrical holes filled with phase change material (PCM). The objective of incorporating the PCM into the concrete roof is to increase the value of thermal mass of the roof. The PCM absorbs the heat through the melting process before it reaches the indoor space, and thus reducing the heat gain. Numerical method is extensively utilized in this research and it is validated with experimental work. The thermal effectiveness of the proposed concrete roof with PCM is assessed by comparing the heat flux at the indoor surface with that of solid concrete roof during the day. A parametric study is conducted to evaluate the effects of the cylindrical holes dimension, PCM melting temperature, and operating month on the heat gain. The results indicate that heat gain can be reduced significantly with larger PCM holes diameter. The PCM melting temperature of PCM should be selected based on the operating month and working hours for the best performance. For the examine cases in this research, the heat flux at the indoor surface of the roof is reduced between 9% and 17.26%, depending on the selected PCM, working hours, and operating month.

14/00961 Curbing global warming with phase change materials for energy storage

Anisur, M. R. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 23–30.

The application of thermal energy storage (TES) system with phase change material (PCM) is an effective way for energy conservation and greenhouse gas (GHG) emission reduction. Global warming is increasing along with the energy consumption. Many researchers are concerned about this present global environmental problem for fossil-fuel burning. Thermal energy storage system with phase change material is observed as a potential candidate for mitigating this problem. This paper emphasizes the opportunities for energy savings and greenhouse-gas emissions reduction with the implementation of PCM in TES systems. For instance, about 3.43% of CO_2 emission by 2020 could be reduced through the application of PCM in building and solar thermal power systems. Similarly, energy conservation and GHGs emission reduction by other PCM applications for thermal comfort of vehicles, transport refrigeration, engine cold start, greenhouse and waste heat management are also presented. In addition, some present investigations on the performance improvement of the phase change materials are addressed.

14/00962 De- and rehydration of $Ca(OH)_2$ in a reactor with direct heat transfer for thermo-chemical heat storage. Part A: experimental results

Schaube, F. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 856–864.

Heat storage technologies are used to improve energy efficiency of power plants and recovery of process heat. Storing thermal energy by reversible thermochemical reactions offers a promising option for high-storage capacities especially at high temperatures. Due to its low material cost the use of the reversible reaction $Ca(OH)_2 \rightleftharpoons CaO + H_2O$ has been suggested. This paper reports on the thermal behaviour of a reactor with direct heat transfer between the gaseous reactant and the solid material. Cycling stability is confirmed and the impact of the most significant parameters such as the maximum possible enthalpy difference of the heat transfer fluid between inlet and outlet, the heat transfer, the particle reaction rate and the mass transport is derived. In the test system the particle reaction rate could be identified as the main limiting parameter.

14/00963 De- and rehydration of $Ca(OH)_2$ in a reactor with direct heat transfer for thermo-chemical heat storage. Part B: validation of model

Schaube, F. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 865–873.

Heat storage technologies are used to improve energy efficiency of power plants and recovery of process heat. Storing thermal energy by reversible thermochemical reactions offers a promising option for high storage capacities especially at high temperatures. Due to its low material cost the use of the gas–solid reaction $Ca(OH)_2 \rightleftharpoons CaO + H_2O$ has been suggested. In Part A of this work the thermal behaviour of a reactor with direct heat transfer was experimentally investigated. In this part a two-dimensional model is applied for the specified system. The experimental and simulated results during the exothermic hydration are discussed in order to confirm the validity of the model. The model is validated regarding heat transfer, integral reaction rate and maximum temperatures. In addition, an adaptation of the kinetic equation is proposed in order to take into account rate-limiting effects due to agglomeration in the powder bed.

14/00964 Development and characterization of new shape-stabilized phase change material (PCM)–polymer including electrical arc furnace dust (EAFD), for acoustic and thermal comfort in buildings

Barreneche, C. *et al. Energy and Buildings*, 2013, 61, 210–214.

Energy consumption for thermal comfort in buildings reached 20–40% of total energy consumption in the developed countries. This study evaluates the performance of a composite material with enhanced thermal inertia formulated with a solid waste to be used in buildings. The feasibility of incorporating electric arc furnace dust (EAFD) was evaluated. EAFD is a special waste used as filler in a polymer matrix. Paraffin wax is added with two functions: on one side as lubricant agent to promote a correct mixing between the inorganic filler and the polymeric matrix. Moreover, paraffin acts as phase change material (PCM) due to their high thermal energy storage (TES) capacity as latent heat from the phase change. In order to evaluate the performance as part of building systems of new material developed in this paper, several composite formulations were prepared and tensile strength test were performed, the thermal properties were analysed by differential scanning calorimetry and airborne noise acoustic properties were tested using an experimental cabin based on the UNE-EN-ISO140. The results were compared with a commercial material for acoustic insulation in constructive solutions. The material developed was a 3 mm dense sheet able to be used in combination with other materials as constructive systems.

14/00965 Discrete model-based operation of cooling tower based on statistical analysis

Wang, J.-G. *et al. Energy Conversion and Management*, 2013, 73, 226–233.

This study is aimed to utilize the operation data to build a physical-meaningful and precise-enough model to assist the operation of a cooling tower. To do so, this work introduces a dimensionless index, which can describe the cooling capability of a cooling tower in terms of effective power utilization. In the first phase of this study, principal component analysis, one of factor analysis methods, is used to investigate effects of ambient air temperature and relative humidity on the cooling capability of a cooling tower. Based on the proposed cooling capability index, the operation data are partitioned into different groups by the fuzzy c-mean clustering algorithm. The resulted groups are distinctly categorized by the conditions of ambient air temperature and relative humidity. In the second phase of the study, data within the same mode of a set of fans are partitioned by the fuzzy c-mean clustering algorithm. The resulted groups of data are then modelled by linear regression. The acquired multiple models are highly accurate in predicting the output temperature of cooling water from the cooling tower. The acquired models assist the operator to accurately select the proper fan mode when process conditions, e.g. cooling loading, or environment conditions, e.g. ambient air temperature, change, which results in electricity saving. This study is concluded by the presentation of a discrete model-based approach to determine the fan mode. The application to a real cooling tower in an iron and steel plant is promising in saving electricity consumed by the fan set.

14/00966 Dynamic heat exchanger model for performance prediction and control system design of automotive waste heat recovery systems

Horst, T. A. *et al. Applied Energy*, 2013, 105, 293–303.

Waste heat recovery by means of a Rankine cycle is a promising approach for achieving significant reductions in fuel consumption and, as a result, exhaust emissions of passenger car engines. This approach is already well established in industrial applications such as gas and steam power plants or ship propulsion systems. While these systems are mainly designed for stationary operation, the behaviour in highly dynamic operating conditions becomes more important when the principle is transferred to a passenger car engine. Knowledge of the dynamic response of the employed heat exchangers plays an important role in performance prediction and control system design of the steam cycle. Hence, a dynamic model of the exhaust gas heat exchanger employing the moving-boundary principle was developed and is presented in this paper. The model describes both design operation and the heat-up procedure of the component. For achieving high model accuracy in the resulting broad range of operating conditions, new approaches for modelling wall temperature distribution and zone switching were developed. Simulations of stationary operating points as well as the response to typical disturbances of the system's input variables are in good agreement with test bench measurements. The model is used to develop a control system for dynamic operation on the test bench. Further studies of the operating characteristics reveal varying dynamic behaviour depending on the heat flow rate from exhaust gas to working fluid as well as coupling of evaporation pressure and outlet steam temperature.

14/00967 Effect of stitch on thermodynamic properties of sandwiched thermal protection structures

Ai, S. *et al. Composite Structures*, 2013, 99, 41–47.

The thermodynamic behaviour of stitched thermal protection structures is simulated using the finite-element method. The effects of stitching step on the thermal protection capability and the induced thermal stress in the stitched sandwich structures are numerically analysed by ABAQUS codes. The stitched sandwich specimens consist of three components: the upper and lower skins, the heat insulation core and the stitches, and it modelled as a discrete stitched three-layer structure. The structure is subjected to re-entry heating corresponding to the access to space vehicle. Two numerical models, for the in-depth heat transfer and for the thermoelastic deformation, are coupled to yield the transient response of the stitched sandwich structures. A heating temperature of 1273 K with constant temperature, isothermal and periodic mechanical boundary conditions are considered. The transient temperature distribution and resultant thermal stresses are then computed. Five different stitching steps are considered and the results of simulations showed that: The ability of stitches in the stitched sandwich structures to improve heat conductivity is limited; however, it has significant influence on thermal stress in the stitched sandwich structures.

14/00968 Enhanced performances of macro-encapsulated phase change materials (PCMs) by intensification of the internal effective thermal conductivity

Calvet, N. *et al. Energy*, 2013, 55, 956–964.

Performances of spherical macrocapsules (nodules) currently used in latent heat-based thermal energy storage (TES) industrial units have been enhanced by the addition of graphite particles to the phase change material (PCM). Two different graphite types, namely graphite flakes (GF) and expanded natural graphite (ENG), have been tested at constant PCM content in the nodule. Using water as PCM, both graphite types have been proven to lead to significant reduction in storage/discharge durations (up to 35% and 58% for a graphite load of only $13\%_{\mathrm{wt}}$) without reduction in storage capacity. Therefore, enhancement using ENG greatly enhances efficiency, but it is also more expensive. GF maybe preferred, considering both its ease of use and economic issues. At the highest experimented graphite load ($13\%_{\mathrm{wt}}$) the overall thermal behaviour of the nodule is advantageously improved, with simultaneously no apparent supercooling, a very stable phase change plateau, and very sharp and straight sensible heat exchange periods. The graphites induce both extensive thermal power enhancement and improvement in thermal behaviours. These experimental results have been simulated using numerical Comsol®-based models with success. The simulated charge/discharge steps have shown that the air gap present in the nodules induces modifications in the phase change front profile only at the beginning of the periods.

14/00969 Enhanced thermal conductivity of uranium dioxide–silicon carbide composite fuel pellets prepared by spark plasma sintering (SPS)

Yeo, S. *et al. Journal of Nuclear Materials*, 2013, 433, (1–3), 66–73.

Uranium dioxide (UO_2)–10 vol% silicon carbide (SiC) composite fuel pellets were produced by oxidative sintering and spark plasma sintering (SPS) at a range of temperatures from 1400 to 1600 °C. Both SiC whiskers and SiC powder particles were utilized. Oxidative sintering was employed over 4 h and the SPS sintering was employed only for 5 min at the highest hold temperature. It was noted that composite pellets sintered by SPS process revealed smaller grain size, reduced formation of chemical products, higher density, and enhanced interfacial contact compared to the pellets made by oxidative sintering. For given volume of SiC, the pellets with powder particles yielded a smaller grain size than pellets with SiC whiskers. Finally thermal conductivity measurements at 100, 500 and 900 °C revealed that SPS sintered UO_2–SiC composites exhibited an increase of up to 62% in thermal conductivity compared to UO_2 pellets, while the oxidative sintered composite pellets revealed significantly inferior thermal conductivity values. The current study points to the improved processing capabilities of SPS compared to oxidative sintering of UO_2–SiC composites.

14/00970 Enhancement of heat transfer for thermal energy storage application using stearic acid nanocomposite with multi-walled carbon nanotubes

Li, T. *et al. Energy*, 2013, 55, 752–761.

A latent heat storage nanocomposite made of stearic acid (SA) and multi-walled carbon nanotube (MWCNT) is prepared for thermal energy storage application. The thermal properties of the SA/MWCNT nanocomposite are characterized by SEM (scanning electron microscopy) and DSC (differential scanning calorimeter) analysis techniques, and the effects of different volume fractions of MWCNT on the heat transfer enhancement and thermal performance of stearic acid are investigated during the charging and discharging phases. The SEM analysis shows that the additive of MWCNT is uniformly distributed in the phase change material of stearic acid, and the DSC analysis reveals that the melting point of SA/MWCNT nanocomposite shifts to a lower temperature during the charging phase and the freezing point shifts to a higher temperature during the discharging phase when compared with the pure stearic acid. The experimental results show that the addition of MWCNT can improve the thermal conductivity of stearic acid effectively, but it also weakens the natural convection of stearic acid in liquid state. In comparison with the pure stearic acid, the charging rate can be decreased by about 50% while the discharging rate can be improved by about 91% respectively by using the SA/5.0% MWCNT nanocomposite. It appears that the MWCNT is a promising candidate for enhancing the heat transfer performance of latent heat thermal energy storage system.

14/00971 Evaluation of adding flash tank to solar combined ejector–absorption refrigeration system

Sirwan, R. *et al. Solar Energy*, 2013, 91, 283–296.

Performance of the absorption cooling system is still a challenge due to the coefficient of performance (COP) that is generally poor when compared with the conventional vapour compression cycle. High solar radiation in hot climates is usually associated with high ambient temperature and consequently peak cooling demand. Absorption cooling cycles can be powered by solar but the performance is limited by heat source temperature (solar collector) and high ambient temperature that can affect the condensation process. Efficiency enhancement of the system components is essential to increase the COP of the system. A modification in the combined absorption–ejector cooling system is adopted. Adding a removable flash tank between the condenser and evaporator could improve entrainment ratio of the ejector, along with improving the cooling effect inside the evaporator. A computer simulation program is developed to evaluate the performance of the modified combined cycle using aqua-ammonia (NH_3–H_2O) refrigerant. The performance of the proposed combined cooling cycle is compared with basic absorption, and combined absorption–ejector cooling cycles. Results showed a significant improvement in the COP of the modified cycle at different operating conditions. Cooling effect and capacity of the evaporator is enhanced due to the reduction of flash gas delivered to the evaporator. Furthermore, the flash tank optimized the ejector entertainment ratio and consequently increasing the condenser pressure. This optimization will enable the system to perform well in hot climates where the condenser efficiency is limited by ambient temperature.

14/00972 Evaluation of thermal conductivity for thermally insulated concretes

Yun, T. S. *et al. Energy and Buildings*, 2013, 61, 125–132.

Passive energy-saving houses and buildings made of thermally insulated materials become popular in recent construction practices to address the demanding energy needs and to reduce the consumption of hydrocarbon energy resources. Thermally insulated concretes represent alternative construction materials to improve the thermal efficiency in a wide range of residential and commercial buildings. This study presents the experimental results of thermal conductivity values of lightweight concrete materials at ambient temperature conditions. Various lightweight aggregates and glass bubbles are selected as surrogates and replacement materials for coarse aggregates in order to reduce the thermal conduction in concretes. The linear and plane heat source methods are implemented to quantitatively obtain conductivity values for tested specimens. Results highlight that the thermal conductivity of concretes can be effectively reduced with increasing fraction of lightweight aggregates critically depending on the type of lightweight aggregates, thereby playing an important role in the thermal insulation. The addition of micrometre-sized hollow glass bubbles further decreases the thermal conductivity of specimens while its impact is less pronounced than the lightweight aggregates. The measurement of strength corroborates the soundness of mechanical applicability of tested concretes specimens as well.

14/00973 Exergy analysis and comparison of multi-functional heat pump and conventional heat pump systems

Sun, X. *et al. Energy Conversion and Management*, 2013, 73, 51–56.

In this paper, the thermal dynamic analysis of a multi-functional heat pump system (MHPS) is made in comparison with a conventional heat pump air conditioning system. Energy and exergy efficiencies of the different systems are calculated to study influences of the components parameters, operation conditions and operation modes on the system performance. Variation of the MHPS performance with increasing hot water temperature is investigated, and performances of the major components are also studied in order to optimize the structure and operation of MHPS. The results show the following: (1) with an outdoor air temperature of 35 °C, for MHPS under space cooling with domestic hot water (DHW) mode, as expected, energy efficiency is 10.12% enhanced and exergy loss ratio is 9.06% reduced in comparison with that of a conventional air-conditioning system under space cooling mode. (2) With an outdoor air temperature of 7 °C, compared to the conventional air conditioning system under space heating mode, the energy efficiency of MHPS under space heating with DHW mode is 3.3% enhanced. While the exergy loss ratio of MHPS is about 1% higher than that of the conventional air conditioning system. (3) Under space heating with DHW mode, condensing heat of MHPS are supplied to meet the requirements of both space heating and water heating simultaneously. Though when the inlet water temperature is low, the exergy loss ratio of MHPS is high, and since most condensing heat is taken by the water-heating condenser, heat supplied for air conditioning would be insufficient. Thus time-sharing supply of hot water and space heating is suggested. In a practical application, space heating is usually taken as first priority. When water temperature is lower than a set point, water heating should be processed when space heating is not required. And as long as space heating is required, MHPS would operate without water heating if the inlet water temperature is lower than the set point.

14/00974 Experimental and numerical study of a usual brick filled with PCM to improve the thermal inertia of buildings

Hichem, N. *et al. Energy Procedia*, 2013, 36, 766–775.

The integration of a phase change material (PCM) layer into an external building wall diminished the amplitude of the instantaneous heat flux through the wall. The types of PCM, its location in the wall and its amount, have been studied in this paper. A two-dimensional transient heat transfer model has been developed and solved numerically using a commercial computational fluid dynamics program. The numerical results have been verified and validated with an experimental model. The considered model consists of usual brick with square holes used as construction materials for residential buildings in Algeria, some of these square holes are filled with PCM. The results showed that the PCM introduced in square holes can improve considerably the thermal inertia of brick and a combination of the types of PCM, its location in the wall and its amount, is very important for improve reduction of heat gain before it reaches the indoor space.

14/00975 Experimental investigation and performance analysis of a ground-coupled heat pump system

Zhai, X. Q. *et al. Geothermics*, 2013, 48, 112–120.

A ground-coupled heat pump system using heat recovery technology was developed for a cooling-dominated building. According to experimental results, an increment in soil temperature of about 0.5 °C was observed after a year of operation. The long-term performance analysis shows that the increase in soil temperature is one third of that without heat recovery. The higher the set value of indoor temperature, the lower is the increase in soil temperature after long-term operation. The distance between the boreholes is suggested to be 4–5 m in urban areas with limited space for the installation of ground heat exchangers.

14/00976 Experimental investigation of low-pressure refrigerant mixtures for micro cryogenic coolers

Lewis, R. *et al. Cryogenics*, 2013, 54, 37–43.

Micro cryogenic coolers (MCCs) can achieve very small sizes and high efficiencies when operating with a refrigerant mixture, but micro-scale compressors have a limited pressure output. Four refrigerant mixtures were designed to operate between 0.4 and 0.1 MPa, and tested in a MCC system both with and without pre-cooling. For comparison, two pure refrigerants were tested as well. Without pre-cooling, each mixture exhibited considerably lower cooling power than the design value. With pre-cooling, the mixtures exhibited unsteady cooling temperatures accompanied by flow pulsations after a period of time. The low cooling power, unsteady temperatures, and time required for the pulsations to occur are analysed in terms of composition change due to liquid hold-up in the annular and intermittent flow regimes.

14/00977 Experimental investigation on isothermal performance of the micro-grooved heat pipe

Tang, Y. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 143–149.

The micro-grooved heat pipe (MGHP), which has grooves in the inner wall, is widely used in electronic heat dissipation at high heat flux. It was made via the technology of vacuuming and filling working fluid. The isothermal performance of MGHP was analysed in the first vacuuming, filling rate of working fluid and second vacuuming. The experimental results show the following conclusions: first, the MGHP in low vacuum degree has more remarkable temperature drop than that in high vacuum degree. The maximum slope of temperature distribution curve of the MGHP in low vacuum degree moves to gas-gathering section with the increase of the heating temperature. Second, increasing the first vacuuming time does not always improve the isothermal performance remarkably. There exists optimal first vacuuming time, such as 30 s in this study. Third, at high working temperature, with increasing the filling rate of working fluid (ranges from 80% to 120%), the temperature difference between the evaporator and the end of condenser generally increases. Fourthly, second vacuuming has a remarkable influence on the isothermal performance of the MGHP. After second vacuuming, the MGHP has a small value of temperature difference that is nearly half of the initial value between the evaporator and the end of condenser. In this experiment, a second vacuuming time at 30 s and a second vacuuming temperature at 100 °C are preferred parameters.

14/00978 Experimental investigations of fouling reduction in an ultrasonically-assisted heat exchanger

Legay, M. *et al. Experimental Thermal and Fluid Science*, 2013, 46, 111–119.

The aim of this study is to investigate the potential use of ultrasonic waves directly applied to a heat exchanger structure in order to clean some fouling layers. The heat exchanger is a double-pipe configuration where the central pipe is removable. Glass and stainless steel central pipes were tested after being painted with spraying paint to simulate some fouling layers. The fouling reduction, or paint removal, can be illustrated visually or by plotting the evolution of either the overall heat transfer coefficient or the fouling thermal resistance with time as the paint is removed. Results are very encouraging since the fouling layers can be removed both from the external side of the pipe and, with more difficulties, from the internal side. Therefore, the overall heat transfer coefficient, previously decreased by the thermal resistance of the paint thickness, can be found again up to its initial value, corresponding to that of a clean tube.

14/00979 Experimental study of thermal energy storage characteristics of a paraffin in a horizontal tube-in-shell storage unit

Avci, M. and Yazici, M. Y. *Energy Conversion and Management*, 2013, 73, 271–277.

In this study, the latent heat thermal energy storage system of the horizontal shell-and-tube type is experimentally analysed. Paraffin is used as the phase change material (PCM) while the distilled water is used as the heat transfer fluid. At first, the thermophysical properties of the paraffin used are determined through the differential scanning calorimeter analysis. Experiments are conducted to investigate not only the storage behaviour (melting or charging) but also the removal one (solidification or discharging) of the PCM. Effect of the inlet temperature on the melting (for the charging) and solidification (for the discharging) time is determined. The focus is on the understanding the physics of the process based on the temporal variation of temperature field inside the PCM.

14/00980 Experimental study on phase change spray cooling

Hou, Y. *et al. Experimental Thermal and Fluid Science*, 2013, 46, 84–88.

Phase change spray cooling is known as an effective method to remove heat from high-power electronic devices due to its high heat transfer efficiency and high critical heat flux (CHF). In this study, a closed-cycle spray cooling system with R22 as the coolant was designed and built, and the system cooling performance including the heat transfer coefficient, cooling surface temperature and CHF was experimentally investigated with nozzle inlet pressure in the range of 0.6–1.0 MPa. The system shows a great capability in removing high heat flux from the cooling surface at a relatively low temperature. As the nozzle inlet pressure increases, the value of CHF first increases and then decreases slightly. The maximum CHF of 276.1 W cm^{-2} is achieved at the nozzle inlet pressure of 0.8 MPa and the corresponding cooling surface temperature is 26.8 °C.

14/00981 Experimental study on the performance of recooling cycle of hydrocarbon fueled scramjet engine

Qin, J. *et al. Fuel*, 2013, 108, 334–340.

Recooling cycle (RCC) has been newly proposed as a new cooling method to increase fuel heat sink (cooling capacity). A testing system is established and an experimental study is conducted on the operating characteristics and performance of RCC with different flow, heat transfer and cracking conditions. Experimental results indicate that the utilization of fuel heat sink is restricted by the allowable material temperature of heated tube; RCC provides another chance for the continued use of fuel chemical heat sink and the repeated use of fuel physical heat sink in the secondary cooling by reducing the fuel temperature by doing work to turbine, and the total heat sink of fuel can be increased to 0.7 MJ/kg when n-decane is used as the fuel. RCC can also improve the ‘olefin/paraffin ratio’ of cracking reaction, which facilitates the improvement of the combustion performance of fuel.

14/00982 Heat transfer and fluid flow characteristics of laminar flow past an open cavity with heating from below

Stiriba, Y. *et al. International Communications in Heat and Mass Transfer*, 2013, 43, 8–15.

Laminar mixed convective flow over a three-dimensional open cavity with heating from below at constant temperature was numerically simulated using direct numerical simulation and the most hydrodynamic and thermal aspects of the flow are presented. The effects over the velocity and temperature distribution of the buoyancy forces acting perpendicular to the mainstream flow are studied for a range of Reynolds numbers between 100 and 1500, and Richardson numbers from 0.001 to 10 to obtain a phenomenological description of the convective air flowing through the channel and the cavity. At low Reynolds and Richardson numbers the flow becomes steady and the heat diffusion is predominant, whereas at high Richardson number the heat transfer by convection becomes important and the flow experiences unsteady behaviour with a significant interaction between the external flow and the recirculating flow inside the cavity, and exhibits a three-dimensional nature.

14/00983 Heat transfer characteristics of a centrifugal heat sink

Kim, J. and Kim, S. J. *International Journal of Heat and Mass Transfer*, 2013, 56, (1–2), 186–196.

A novel heat sink, called a centrifugal heat sink, into which the blades of a fan are integrated between the fins, is proposed. The fan blades, based on design principles of centrifugal turbomachinery, are arranged to be placed between the fins of the circular heat sink. The rotary motion of the blades causes nearby coolant to be sucked into and pass through channels formed by adjacent fins. Due to the integration of the blades into the space between the fins, additional space for the blades of the fan is no longer required for the centrifugal heat sinks. Consequently, this centrifugal heat sink makes efficient use of available cooling space. In this paper, an experimental investigation is conducted to demonstrate the concept of the centrifugal heat sink. As the speed of the fan increases, the average velocity is shown to increase proportionally. To evaluate the thermal performance of the centrifugal heat sink under constant heat flux conditions, the maximum temperature at the heat sink base is measured. As a result, the minimum thermal resistance of the centrifugal heat sink is found to be 0.47 K/W. In order to estimate the required pumping power and the thermal resistance, a theoretical model is also developed and validated using experimental results. From the theoretical model, optimized centrifugal heat sinks have lower thermal resistances than optimized plate-fin heat sinks under the fixed pumping power condition.

14/00984 Heat transfer enhancement of neopentyl glycol using compressed expanded natural graphite for thermal energy storage

Wang, X. *et al. Renewable Energy*, 2013, 51, 241–246.

Neopentyl glycol (NPG) was saturated into the compressed expanded natural graphite (CENG) matrices with different densities in an attempt to increase the thermal performance of NPG for latent heat thermal energy storage (LHTES) application. NPG uniformly disperses in the porous network of the expanded graphite. Measured results indicated that thermal conductivities of the composites can be enhanced 11–88 times as compared with that of the pure NPG. The latent heat of the NPG/CENG composites increased with the increasing mass ratio of the NPG in the composites. Compared with the pure NPG, the deformation of the composites due to phase change has been greatly reduced. After phase transition, thermal conductivity of the composites decreased slightly. The trends concluded from the finite element simulation are coincident with the trends from the thermal imager.

14/00985 Influence of particle concentration and temperature on thermal conductivity and viscosity of Al_2O_3/R141b nanorefrigerant

Mahbubul, I. M. *et al. International Communications in Heat and Mass Transfer*, 2013, 43, 100–104.

Refrigerant-based nanofluids are termed as nanorefrigerants. They have the potential to enhance the heat transfer performances of refrigeration and air-conditioning systems. In this paper, thermal conductivity and viscosity of the Al_2O_3/R141b nanorefrigerant for 0.5–2 vol.% concentrations at temperatures of 5–20 °C have been investigated. Al_2O_3 particles with average diameters of 13 nm were used with the R141b refrigerant. The experimental results show that, thermal conductivity of the Al_2O_3/R141b nanorefrigerant increased with the augmentation of particle concentrations and temperatures. Besides, viscosity of the nanorefrigerant increased with the increase of volume fractions. However, this parameter decreased accordingly with the increment of temperature. The highest thermal conductivity and viscosity were observed to be 1.626 and 179 times greater than the base fluid for 2 volume concentration (%) of particles, respectively. Therefore, optimal concentrations of nanoparticles need to be dispersed in the refrigerant considering the thermal conductivity and viscosity for better heat transfer performance.

14/00986 Investigation of buoyancy effects on heat transfer between a vertical borehole heat exchanger and the ground

Sharqawy, M. H. *et al. Geothermics*, 2013, 48, 52–59.

In this paper, the heat transfer from a vertical borehole heat exchanger in the presence of groundwater is investigated using a general convection–conduction heat transfer model. The model can be used for estimating the required length of the borehole for a given constant heat load in locations with or without groundwater. All thermal resistances involved in the heat transfer process between the borehole heat exchanger and the surrounding ground are taken into consideration. In addition, the effect of heat transfer from the ground surface to the ambient is investigated. A comparative case study is presented to illustrate the differences in estimating the length of a vertical borehole heat exchanger based on the proposed model in comparison with other methods that are based on conduction only mode of heat transfer. It is found that the natural convection heat transfer arises from the presence of groundwater increases the heat flux from the borehole surface. Consequently, the required borehole length decreases by about 50% at soil permeability of 5×10^{-9} m^2. In addition, a convective type ground surface reduces the length by about 10% compared with an adiabatic surface assumption.

14/00987 Investigation of synchronous effects of multi-mesh regenerator and double-inlet on performance of a Stirling pulse tube cryocooler

Arablu, M. and Jafarian, A. *Cryogenics*, 2013, 54, 1–9.

In this paper synchronous effects of multi-mesh regenerator and double-inlet on performance of a Stirling pulse tube cryocooler (SPTC) have been considered. In this respect, a finite volume code was developed to simulate the SPTC. Set of governing equations were written in a general form such that all porous and non-porous sections of the system could be modelled. Results showed that synchronous application of double inlet and multi-mesh regenerator optimizes the phase shift between velocity and pressure at the warm end of the pulse tube, increases the regenerator's outlet pressure amplitude, decreases inertial and viscous losses in the hot end of the regenerator and consequently increases the coefficient of performance (COP) of the system. Furthermore, it was observed that a minimum temperature of 60.3 K and COP of 0.03996 @ 80 K is attainable using optimum multi-mesh regenerator and double inlet; whereas, for a simple SPTC with a uniform mesh regenerator, a minimum temperature of 71.3 K and maximum COP of 0.0227 @ 80 K are concluded.

14/00988 Magnetocaloric effect: a review of the thermodynamic cycles in magnetic refrigeration

Romero Gómez, J. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 74–82.

Magnetic refrigeration (MR) at room temperature is an emerging technology and shows real potential to enter conventional markets. The principle of MR obeys the magnetocaloric effect (MCE), which is based on the effect caused by a magnetic field on the materials that bear the property of varying the magnetic entropy, as well as its temperature, when varying the magnetic field. In this paper, both the theory and thermodynamics of the MCE as well as the characteristics and properties required in the magnetocaloric material for MR will be reviewed. The most suitable materials for room temperature MR as well as those that display a promising future are also reviewed. A presentation and description is given of the Carnot, Brayton, Ericsson, active magnetic regenerator (AMR) and cascading MR cycles with a view to establishing selection criteria based on their performances. The MCE cannot be used directly for cooling; instead specialized cooling cycles with regeneration are required for MR to be used for cooling at room temperature at an effective cost. Not all the described MCE-based refrigeration cycles can be applied in refrigeration technology at room temperature. In this way, the Carnot cycle can only be effective in cryogenic applications. Nevertheless, the regenerative Brayton and Ericsson cycles are well suited to real applications with little differences between them. The AMR cycle is the most used MR cycle at room temperature due to its greater performance in comparison with the other cycles. Therefore, all implemented prototypes so far are based on the AMR cycle. The main refrigerating material used in MR prototypes so far is Gd and its alloys. This is attributed essentially to its good MCE at room temperature, good mechanical properties, low hysteresis, commercial availability and its capacity to meet the needs of engineering. However, its high cost limits its use in large-scale applications. Numerous studies of magnetocaloric materials have been carried out to find alternatives to Gd and are currently the main research field for room temperature MR. Giant magnetocaloric effect materials reach high isothermal entropy change (ΔS_m) and adiabatic temperature change (ΔT_{ad}) values, yet few test devices have been built and studied to determine their performance. These giant MCE materials exhibit problems arising from the nature of their phase transition. In this way, the La(Fe$_{1-x}$Co$_x$)$_{11.9}$Si$_{1.1}$series could become the room temperature magnetocaloric materials of the future, thanks to their mature industrial scale manufacturing process. Based on the results of the discussion, it is highlighted that the MR provides an effective alternative to refrigeration based on vapour compression, due to the benefits of using the MCE.

14/00989 Margin design, online optimization, and control approach of a heat exchanger network with bypasses

Luo, X. *et al. Computers & Chemical Engineering*, 2013, 53, 102–121.
During the life cycle operation of a heat exchanger network (HEN), factors such as equipment aging, gradually decrease heat transfer performance and increase energy consumption. Industrial HEN design currently fails to effectively solve these problems. To resolve this problem, the authors present an online optimization and control approach method for an HEN with bypasses. The approach is based on the principles of sustainable energy conservation during the life cycle. The area margin of the heat exchanger is gradually released via bypass adjustment, thereby resulting in energy conservation. First, bypasses are set on the HEN to enhance HEN control and enable optimal manipulation of the equipment. Then, the total cumulative cost increment of the HEN, including the increment of utility costs and equipment investment costs, is regarded as the objective function. The effects of the heat transfer efficiency of the heat exchanger and the effects of bypass adjustment are also taken into account. The authors solve the optimal design margin of the HEN, thereby providing an operational space for optimal control. Finally, using the margin optimization design of the HEN with bypasses as basis, the authors treat the cumulative costs of the HEN in a certain cycle as the objective function to solve the optimal opening dynamically. An optimal control structure is presented, which is combined with existing conventional control loops. The HEN of a given crude distillation unit in a refinery is chosen as the research object. And, results illustrate the effectiveness and application prospects of the proposed method.

14/00990 Mathematical modeling and experimental verification of an absorption chiller including three dimensional temperature and concentration distributions

Jayasekara, S. and Halgamuge, S. K. *Applied Energy*, 2013, 106, 232–242.
One of the main drawbacks in modelling absorption chillers is the lack of justified hypotheses of heat and mass diffusion in an annular flow on the outer surface of horizontal tubes. Heat and mass transfer in diffusion is a three-dimensional problem with vector characteristics. This paper introduces the characterization of vapour–absorbent heat and mass transfer phenomena in three dimensional space to obtain steady state simulation results for single effect LiBr–H$_2$O absorption chillers. It is thus possible for the first time to ascertain in the simulation that the heat and mass transfer characteristics are not uniform throughout the solution film. The diffusion boundary layer gradually becomes thicker towards the downstream tubes, which has previously been assumed but never confirmed in simulations. The radial component of the concentration field exhibits a potential for determining an optimum film thickness which enhances the system performance. The ability to use the proposed model with various absorbents and different cooling capacities increases its applicability. The model also offers the possibility to analyse different firing techniques at different temperatures. All the simulation results are consistent with the experimental data found in the literature.

14/00991 Mathematical programming model for heat exchanger design through optimization of partial objectives

Onishi, V. C. *et al. Energy Conversion and Management*, 2013, 74, 60–69.
Mathematical programming can be used for the optimal design of shell-and-tube heat exchangers (STHEs). This paper proposes a mixed integer non-linear programming (MINLP) model for the design of STHEs, following rigorously the standards of the Tubular Exchanger Manufacturers Association. The Bell–Delaware method is used for the shell-side calculations. This approach produces a large and non-convex model that cannot be solved to global optimality with the current state of the art solvers. Notwithstanding, it is proposed to perform a sequential optimization approach of partial objective targets through the division of the problem into sets of related equations that are easier to solve. For each one of these problems a heuristic objective function is selected based on the physical behaviour of the problem. The global optimal solution of the original problem cannot be ensured even in the case in which each of the sub-problems is solved to global optimality, but at least a very good solution is always guaranteed. Three cases extracted from the literature were studied. The results showed that in all cases the values obtained using the proposed MINLP model containing multiple objective functions improved the values presented in the literature.

14/00992 Micro-channel pressurized-air solar receiver based on compact heat exchanger concept

Li, Q. *et al. Solar Energy*, 2013, 91, 186–195.
This paper investigates the thermal performance of pressurized air solar receiver for applications in concentrating solar power (CSP) systems. The design is imagined and manufactured based on compact heat exchanger (CHE) concept. An experimental set-up has been built and a series of experiments are carried out under realistic concentrated solar irradiation conditions. The performances of the micro-channel pressurized air solar receivers have been studied in the following parameter ranges: pressure, 2–6 bar; air mass flow rates, 0.431–0.862 $\mathrm{g\,s^{-1}}$, solar flux density 170–470 $\mathrm{kW\,m^{-2}}$ and temperature elevation, 100–360 °C. Derived heat transfer coefficients reach 750 $\mathrm{W\,m^{-2}\,K^{-1}}$.

14/00993 Microencapsulated n-alkane with p(n-butyl methacrylate-co-methacrylic acid) shell as phase change materials for thermal energy storage

Qiu, X. *et al. Solar Energy*, 2013, 91, 212–220.
This study deals with fabrication and characterization of p(n-butyl methacrylate-co-methacrylic acid) shell (P(BMA-co-MAA)) microcapsules containing n-alkane as phase change materials (PCMs) for thermal energy storage. The surface morphologies, particle sizes and distributions were studied by scanning electron microscopy. The chemical characterization of P(BMA-co-MAA)/n-alkane microcapsules was determined by Fourier transformed infrared spectroscopy. The thermal properties, thermal reliabilities, thermal stabilities and temperature-regulated property of the microencapsulated n-alkane were investigated by differential scanning calorimetry, thermal gravimetric analysis and infrared thermography. The microcapsules containing n-octadecane or a paraffin wax show high phase change enthalpies of melting (130.3 or 123.9 J/g) and freezing (125.8 or 118.4 J/g). The weight loss temperatures of the P(BMA-co-MAA)/n-alkane microcapsules were significantly increased compared with the raw phase change materials (PCMs). The phase change enthalpies of the P(BMA-co-MAA)/n-alkane microcapsules varied little after thermal cycles. Thermal images showed that the gypsum board with incorporated P(BMA-co-MAA)/n-octadecane microcapsules possessed temperature-regulated property. As a result, the as-prepared microcapsules show the good potentials for thermal energy storage, such as building materials.

14/00994 Mixed convection from a heated sphere in power-law fluids

Nirmalkar, N. and Chhabra, R. P. *Chemical Engineering Science*, 2013, 89, 49–71.
In this work, the steady, laminar, mixed convection heat transfer from a heated sphere immersed in power-law fluids has been investigated in the so-called aiding-buoyancy configuration. The momentum and thermal energy equations have been solved numerically over the following ranges of conditions: Richardson number, $0 \le Ri \le 2$, power-law index, $0.2 \le n \le 2$, sphere Reynolds number, $1 \le Re \le 100$ and the generalized Prandtl number, $1 \le Pr \le 100$. The detailed kinematics of the flow and temperature fields are visualized in terms of the streamline (stream trace) and isotherm contours in the close proximity of the heated sphere. Further insights are provided in terms of the distribution of pressure coefficient and local Nusselt number along the surface of the heated sphere over wide ranges of conditions from weak to strong free convection flow. Finally, the overall macroscopic characteristics are reported in terms of the individual and total drag coefficients and the surface average Nusselt number as functions of the pertinent dimensionless parameters. The drag coefficient is seen to increase monotonically with the Richardson and Prandtl numbers at low Reynolds numbers and the type of dependence changes at a critical Richardson number. Similarly, the average Nusselt number shows a positive dependence on the Reynolds number, Prandtl number and Richardson number. Broadly, shear-thinning viscosity ($n < 1$) promotes heat transfer over and above that in Newtonian fluids otherwise under identical conditions and, as expected, shear-thickening behaviour ($n > 1$) somewhat impedes it. Finally, the present numerical results have been correlated in terms of the modified Reynolds and Prandtl numbers thereby enabling interpolation of the present results for the intermediate values of the governing parameters.

14/00995 Numerical investigation on weld residual stresses in tube to tube sheet joint of a heat exchanger

Xu, S. and Wang, W. *International Journal of Pressure Vessels and Piping*, 2013, 101, 37–44.
Crack development in weld of the tube-to-tube sheet region of heat exchanger is a common problem. The residual stresses associated with welding can play a major role in this situation. In this paper, the finite element method is used to predict the residual stresses in a tube-to-tube sheet weld. The effect of heat input, preheating temperature, and gap between tube and tube hole on residual stresses was also investigated by numerical simulation. The peak Mises' residual stress occurs in the base metal near the interface between surface welding

layer and base metal. The heat input has little effect on the residual stresses. The maximum residual stress is determined by the yield strength rather than heat input. With the preheating temperature increasing, the peak hoop stresses are decreased. With the gap between tube and tube hole increasing, the residual stresses are increased.

14/00996 Numerical simulation of flow and heat transfer characteristics in wavy fin-and-tube heat exchanger with combined longitudinal vortex generators

Gong, J. *et al. International Communications in Heat and Mass Transfer*, 2013, 43, 53–56.

The air-side heat transfer and fluid flow characteristics of wavy fin-and-tube heat exchanger punched with combined rectangular winglet pairs (CRWPs) were numerically analysed. The influences of several main parameters of the CRWP on heat transfer and friction were examined and compared to rectangular winglet pairs (RWP). The numerical results showed that the wavy fin-and-tube heat exchanger has a better heat transfer performance when the winglets punched on the suction side of the wavy fin. For the wavy fin punched with CRWPs, the Nusselt number and friction factor increase with increases of secondary attack angle, accessory winglet length or accessory winglet width. In comparison with RWP, the vortices generated by CRWP are more, larger and stronger. Hence, CRWP can more effectively improve heat transfer and increase friction.

14/00997 On the heat storage in solar updraft tower collectors – water bags

dos Santos Bernardes, M. C. and Zhou, X. *Solar Energy*, 2013, 91, 22–31.

The goal of this study is to analyse particularly the sensible heat storage physical process in a solar updraft tower collector taking into account the transient heat transfer in ground through conduction, convection and solar radiation and the use of water bags. Simulations were carried out varying the thickness of some water bags sets with and without insulation regarding thermal stratification effect. Results disclosed that thicker water bags can reduce more efficiently the daily temperature spam and thermal stratification is an import thermal effect. Water bags alone are however not enough to break efficiently heat peaks.

14/00998 On the importance of the location of PCMs in building walls for enhanced thermal performance

Jin, X. *et al. Applied Energy*, 2013, 106, 72–78.

Phase change materials (PCMs) are used to enhance the thermal storage capacity of building walls. PCM incorporation into building walls poses several design challenges; a critical one being the integration method (e.g. micro- vs macro-encapsulation) as well as the location of PCMs within the volume of the walls. Such location is critical for wall performance in terms of controlling heat transfer rates for purposes of energy conservation and peak load shifting. This paper highlights the dependence of wall thermal performance on PCM location leading to the most optimal PCM location for the system under study. In this study, PCMs were incorporated in walls via 'thermal shields' where the PCM material was encapsulated in polyethylene flat bubbles 'sandwiched' between two layers of protective aluminium foil. This system is herein referred to as 'PCM thermal shield (PCMTS)'. The thermal performance of the walls with and without PCMTS was evaluated experimentally using a dynamic wall simulator. PCM thermal shields (PCMTSs) were placed within the wall insulation at varying distances from the internal surface of the bounding wallboard, which happened to be the bounding layer furthest from the heating sources of the simulator. For the system under study, the results showed that the optimal location for a PCMTS was at a distance of $1/5L$ from the internal surface of the bounding wallboard, where L was the thickness of the insulation cavity. At this location, the average peak heat flux reduction and load shifting time were approximately 41% and 2 h, respectively, when compared to the peak heat fluxes across walls without PCMTS.

14/00999 One-step approach for heat exchanger network retrofitting using integrated differential evolution

Zhang, H. and Rangaiah, G. P. *Computers & Chemical Engineering*, 2013, 50, 92–104.

Heat exchanger network (HEN) retrofitting is more important and challenging than HEN synthesis since it involves modifying existing network for improved energy efficiency. Additional factors to be considered include spatial constraints, relocation and re-piping costs, reassignment and effective use of existing heat exchanger areas. The previous studies using stochastic global optimization algorithms are mainly focused on two-level approach: the first level uses a stochastic algorithm for optimizing structure, and the second level uses either a stochastic or a deterministic algorithm for optimizing continuous variables. This study proposes and tests one-step approach where a stochastic global optimization method, namely, integrated differential evolution (IDE), handles both discrete and continuous variables together. Thus, HEN structure and retrofitting model parameters are simultaneously optimized by IDE, which avoids the algorithm trapping at a local optimum and also improves the computational efficiency. Results on HEN applications show that the proposed approach gives better solutions.

14/01000 Optimal temperature between high and low stage cycles for R134a/R410A cascade heat pump based water heater system

Kim, D. H. *et al. Experimental Thermal and Fluid Science*, 2013, 47, 172–179.

Single-stage air-source heat pumps have some disadvantages such as a deteriorated heating capacity and low coefficient of performance at low ambient temperatures. To overcome these disadvantages, a cascade cycle has been suggested; this cycle exhibits a better performance at low ambient temperatures. Many studies have investigated the cascade heat pump system. However, little information is available regarding experimental verification of the optimal intermediate temperature levels based on experimental results. In this study, an air-to-water heat pump (AWHP) was studied numerically and experimentally. The high and low cycles of the AWHP adopted R134a and R410A as refrigerants, respectively. Numerical analysis of the optimal intermediate temperature was performed and the experiment was conducted under various operating conditions: ambient temperature, condenser water inlet temperature, and heating capacity. The numerically optimized intermediate temperature accurately predicted the experimental data.

14/01001 Optimization of a cooling system based on Peltier effect for photovoltaic cells

Najafi, H. and Woodbury, K. A. *Solar Energy*, 2013, 91, 152–160.

Temperature increment is one of the main challenges for solar concentrating photovoltaic systems which causes significant reduction in the cell efficiency and accelerates cell degradation. To overcome this issue, a novel cooling method by using Peltier effect is proposed and investigated. In this approach, a thermoelectric cooling module is considered to be attached to the backside of a single photovoltaic cell. It is assumed that the required power to run the thermoelectric cooling module is provided by the photovoltaic cell itself. A detailed model is developed and simulated via MATLAB in order to determine the temperatures within the system, calculate the required power to run the thermoelectric cooling module and the extra generated power by photovoltaic cells due to the cooling effect. Two approaches are investigated to use the proposed system: in the first approach, the goal is controlling the temperature of the photovoltaic cell and keep it under a specific limit for different conditions. In the second approach, a genetic algorithm based optimization is utilized to find the optimal value of the supplied electrical current for the thermoelectric cooling module which leads to the maximum generated power by the system. The result shows that using thermoelectric cooling modules can successfully keep the photovoltaic cell temperature at a low level by using a reasonable amount of electricity.

14/01002 Paraffin/diatomite composite phase change material incorporated cement-based composite for thermal energy storage

Xu, B. and Li, Z. *Applied Energy*, 2013, 105, 229–237.

In this study, thermal energy storage cement-based composite (TESC) was developed by incorporating paraffin/diatomite (DP) composite phase change material (PCM). Paraffin/DP composite PCM was firstly fabricated at mix proportion (paraffin : DP) of 0.9 : 1.0. Scanning electron microscope and Fourier transform infrared results show that paraffin can be well impregnated into DP pores and has good compatibility with it. Differential scanning calorimetry (DSC) results reveal that paraffin/DP composite PCM has melting temperature and latent heat of 41.11 °C and 70.51 J/g, respectively. Good thermal stability is observed for this fabricated composite PCM by using thermogravimetric analysis method. Furthermore, paraffin/DP composite PCM was incorporated in cement-based composite at 10%, 15%, 20% and 30%, by weight of cement. It is found that in comparison with control normal cement-based composite, maximum reductions on 28-day compressive strength and flexural strength, drying shrinkage strain and thermal conductivity by incorporation of paraffin/DP composite PCM are 48.7%, 47.5%, 80.7% and 33.6%, respectively. Good thermal energy storage performance of TESC is clearly suggested by results of specific heat capacity test and heating test.

14/01003 Performances of low temperature radiant heating systems

Bojić, M. *et al. Energy and Buildings*, 2013, 61, 233–238.

This paper reports investigations of energy, environmental, and economic performances of floor, wall, ceiling, and floor–ceiling heating. It is found that the floor–ceiling heating has the best performances: the lowest energy and exergy consumption, exergy destruction, CO_2 emissions (compound, direct, and avoidable), and operation costs. In addition, it uses boiler of the lowest power. The worst system by all these parameters is the classical ceiling heating. The comparison of the room operative air temperatures and the operative air temperatures set by thermostats shows that all systems give satisfactory results without significant deviations. The largest deviation and the lowest values of the surrounding inner surfaces of the exterior walls are found for the floor–ceiling panel system.

14/01004 Phase change material (PCM) storage for free cooling of buildings – a review

Waqas, A. and Din, Z. U. *Renewable and Sustainable Energy Reviews*, 2013, 18, 607–625.

Buildings are responsible for 40% of the total world annual energy consumption and this produces one-third of the world's greenhouse gas (GHG) emissions. A significant portion of this energy is used for lighting, heating, cooling and air-conditioning purposes. Increasing awareness of the environmental impact of GHG emissions and chlorofluorocarbons triggered a renewed interest in environmentally friendly cooling and heating technologies for buildings. Free cooling of buildings may be seen as an alternate to compressor-based air-conditioning systems used for the buildings. In free cooling, night-time cold is accumulated in storage material and extracted when needed. Latent heat storage using phase change materials (PCMs) can be used for free-cooling purposes due to their high storage density. In free cooling, using PCM as storage material, cool air during night is used to solidify the PCM and the accumulated cold is extracted during the hot day times. In this paper a detailed review of work conducted by different researchers on PCM-based free cooling is presented. Major challenges being faced in the design of PCM-based free cooling system such as thermophysical properties and the geometry of encapsulation are elaborated and discussed in detail. The parameters effecting the charging and discharging of PCM, effect of phase change temperature and climatic conditions on thermal performance of the free cooling system are also discussed. Potential reduction in CO_2 emissions due to the applicability of free cooling systems in residential and commercial buildings is also considered. This paper provides a comprehensive list of the PCMs currently being used and that can be used potentially for free cooling applications. Some current problems that require further research in this area are also given.

14/01005 Simulation studies of refrigeration cycles: a review

Anand, S. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 260–277.

A large share of energy consumed is taken up by refrigeration and air conditioning equipment. This study carried out a literature review on refrigeration systems, currently used refrigerant–absorbent pairs and also different sources of energy. The basis of this study was to identify user friendly software used for simulation techniques and also on the scope of different alternative forms of energy as a source of generation. The effects of operating temperature, effectiveness of heat exchangers and choice of working fluid on the systems were also examined. It is evident from the studies that the cycle performance (COP) improves with increasing generator and evaporator temperatures, but reduces with increasing the absorber and condenser temperatures. The use of heat exchangers improves the overall performance of the system, especially solution heat exchangers. It is also evident that solar energy obtained in the range of about 100 °C has the potential to supply sufficient energy to the generator for absorption–refrigeration cycles.

14/01006 Simultaneous synthesis of heat exchanger networks with operability considerations: flexibility and controllability

Escobar, M. *et al. Computers & Chemical Engineering*, 2013, 55, 158–180.

In this work a computational framework is proposed for the synthesis of flexible and controllable heat exchanger networks. The synthesis is projected to operate over a specified range of expected variations in the inlet temperatures and flow rates of the process streams using a decentralized control system, such that the total annual cost involving the utility consumption and the investment are optimized simultaneously. The framework is based on a two-stage strategy. A design stage is performed prior to the operability analysis where the design variables are chosen. In the second stage, the control variables are adjusted during operation on the realizations of the uncertain parameters. The framework yields a heat exchanger networks design, which is guaranteed to operate with the designed control system under varying conditions ensuring stream temperature targets and optimal energy integration. The application of the proposed framework and its computational efficiency are illustrated with some numerical examples.

14/01007 Solid state synthesis, thermodynamics and catalytic combustion effect of a high energy nickel(II) coordination compound

Yang, Q. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 66–70.

Self-assembly of Ni(II) with 3,5-diamino-1,2,4-triazole resulted in a 3D supramolecular compound $[Ni_3(Hdatrz)_6(fma)_2(H_2O)_4]fma \cdot 11H_2O$ (compound 1) in the presence of coligand fumaric acid (Hdatrz = 3,5-diamino-1,2,4-triazole, H_2fma = fumaric acid). X-ray structural analysis reveals that three nickel ions are bridged by six neutral Hdatrz ligands, and abundant lattice water molecules exist in compound 1. Based on the structural framework and TG curve of compound 1, a new energetic compound $[Ni_3(Hdatrz)_6(fma)_2(H_2O)_4]fma$ (compound 2) with 35.5% of nitrogen content was readily prepared through dehydration of compound 1 at 398 K under N_2 atmosphere. The enthalpy change of the reaction of formation for compound 1 was determined to be $(-23.24 \pm 0.05)\,kJ\,mol^{-1}$ by microcalorimetry at $(298.15 \pm 0.01)\,K$. Thermodynamic and thermokinetic parameters k, E, n, $\Delta S^{\theta}_{\neq}$, $\Delta H^{\theta}_{\neq}$ and $\Delta G^{\theta}_{\neq}$ of the reaction of formation for compound 1 were obtained. Thermoanalytical kinetics of the reaction of formation for compound 2 was further investigated. The sensitivity experiment results indicated that compound 2 was more sensitive to impact and friction stimuli that compound 1. As an additive, compound 2 effectively promoted the thermal decomposition of ammonium perchlorate (AP), which projected the potential application of compound 2 as combustion modifier in solid propellants.

14/01008 Splitting the exergy destruction into avoidable and unavoidable parts of a gas engine heat pump (GEHP) for food drying processes based on experimental values

Gungor, A. *et al. Energy Conversion and Management*, 2013, 73, 309–316.

Some limitations in a conventional exergy analysis may be significantly reduced through an advanced exergy analysis. In this regard, the latter is a very useful tool to assess the real potential for improving a system component by splitting the exergy destruction into unavoidable and avoidable parts. This may provide a realistic measure to deduct the improvement potential for the thermodynamic efficiency of a component. For this purpose, improvement efforts are then made by focusing only on these avoidable parts. In this paper, a gas engine heat pump (GEHP) drying system was analysed using both conventional and advanced exergy analyses. Three medicinal and aromatic plants (*Foeniculum vulgare*, *Malva sylvestris* L. and *Thymus vulgaris*) were dried in a pilot scale GEHP drier, which was designed, constructed and installed in Ege University, Izmir, Turkey. Drying experiments were performed at an air temperature of 45 °C with an air velocity of 1 m/s. For each system component, avoidable and unavoidable exergy destructions, modified exergy efficiency values and modified exergy destruction ratios were determined. Except for the compressor, the evaporator and the drying cabinet, most of the exergy destructions in the system components were avoidable and these avoidable parts can be reduced by design improvements. For the HP unit and the overall drying system, the values for exergy efficiency were obtained to be in the range of 82.51–85.11% and 79.71–81.66% while those for the modified exergy efficiency were calculated to be in the range of 85.70–89.26% and 84.50–86.00%, respectively.

14/01009 Supply-based superstructure synthesis of heat and mass exchange networks

Azeez, O. S. *et al. Computers & Chemical Engineering*, 2013, 56, 184–201.

A new simultaneous mixed integer non-linear programing (MINLP) approach to heat exchange network synthesis (HENS) and mass exchange network synthesis (MENS) is presented. This supply-based superstructure (SBS) approach uses the supply temperatures/compositions of all the streams (including utilities) present in the synthesis problem to define heat/mass exchange superstructure intervals. The intermediate temperatures/compositions are variables used in the optimization of the network total annual cost (TAC). The ability of each stream to exchange heat/mass in any interval in the SBS is subject to thermodynamic/mass transfer feasibility. The paper presents the mathematical formulations for optimizing the TAC for HENS and MENS. The SBS synthesis technique has been applied to nine literature problems involving both HENS and MENS. The solutions obtained are in the same range as those in the literature, with one solution being the lowest of all.

14/01010 Theoretical modelling and experimental investigation of a thermal energy storage refrigerator

Marques, A. C. *et al. Energy*, 2013, 55, 457–465.

Numerical simulations using the computational fluid dynamics (CFD) software ANSYS Fluent were undertaken to characterize the airflow and temperature distribution in a natural convection thermal energy storage refrigerator. The model compared the household refrigerator temperature stability with different phase change materials (PCM) incorporated into the storage compartment. Scenarios investigated included the PCM orientation (vertical or horizontal), PCM temperature (use of water or eutectics) and compartment designs (conventional or drawer type appliance). The results suggested that a horizontal PCM configuration produces lower compartment temperatures than a vertical configuration. The temperature distribution with a horizontal PCM was tested experimentally and the results were in agreement with the CFD predictions. Both the simulation and the experimental results suggest that a eutectic with a phase change temperature below 0 °C must be employed to maintain the compartment temperature within acceptable limits. The model indicated that combining horizontal and vertical PCMs in a full height compartment or dividing the same compartment into two drawers with a horizontal PCM configuration for each drawer are feasible design options for the household thermal storage refrigerator.

14/01011 Thermal and exergetic analysis of metal foam-enhanced cascaded thermal energy storage (MF-CTES)

Tian, Y. and Zhao, C. Y. *International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 86–96.

Metal foam-enhanced cascaded thermal energy storage (MF-CTES) has been proposed to solve the problem of poor heat transfer during heat exchange process, which is caused by unavoidable decrease of temperature differences. This paper conducts a theoretical study examining the overall thermal performance of single-stage thermal energy storage (STES), Cascaded thermal energy storage (CTES) and MF-CTES, with both heat exchange rate and exergy efficiency being considered. The main findings are: heat exchange rate of STES is improved by CTES (up to 30%), and is further improved by MF-CTES (by two to seven times); exergy efficiency of STES cannot be significantly improved by CTES (−15% to +30%), nor by MF-CTES; exergy transfer rate of STES is increased by CTES (up to 23%), and is further increased by MF-CTES (by two to seven times).

14/01012 Thermal conductivity of rigid foam insulations for aerospace vehicles

Barrios, M. and Van Sciver, S. W. *Cryogenics*, 2013, 55–56, 12–19.

This study describes measurements of the effective thermal conductivity of NCFI 24–124 foam, a spray-on foam insulation (SOFI) that has been used on the Space Shuttle external fuel tank. A novel apparatus to measure the effective thermal conductivity of rigid foam at temperatures ranging from 20 to 300 K was developed and used to study three samples of NCFI 24–124 foam insulation. In preparation for measurement, the foam samples were either treated with a uniquely designed moisture absorption apparatus or different residual gases to study their impact on the effective thermal conductivity of the foam. The resulting data are compared to other measurements and mathematical models reported in the literature. The thermal conductivity results stress the importance of residual gases present in foams like SOFI. Although launch pad conditions may slightly increase the thermal conductivity of the foam, exposure to high thermal conductivity gases such as helium or hydrogen can have a much greater effect. In the case of hydrogen storage, exposing the foam to venting or leaking hydrogen gas can cause a significant increase in the effective thermal conductivity of the foam.

14/01013 Thermal performance of insulated walls enclosing residential spaces in Thailand

Tummu, P. *et al. Energy and Buildings*, 2013, 61, 323–332.

Vernacular residential houses in Thailand were not heated nor cooled. The walls of such houses were constructed from wood and other light natural materials. Air-conditioning to cool interior spaces is now common and brick and concrete has replaced natural materials for walling. Even when a house is designed for air-conditioning, no insulation is used on the enclosing walls. It is generally believed that thick and heavy walls reduces cooling load in a space but insulation may not and is too costly. This paper presents results from an experimental and simulation study on comparative thermal performance of walls enclosing spaces that are used to serve three residential functions of bedroom, living room, and studio room. The study considers different levels of insulation and its placement at the interior and exterior surfaces on walls with and without windows, and for each functional use of a space. Use of external shading and blinds or curtain is not considered in this study. In all cases, the study concludes that insulation placed at interior wall surface improves wall thermal performance and is superior to that of exterior placement. The latter part appears to contrast with what have been found in similar studies taken under cool climate.

14/01014 Thermal stability of phase change materials used in latent heat energy storage systems: a review

Rathod, M. K. and Banerjee, J. *Renewable and Sustainable Energy Reviews*, 2013, 18, 246–258.

Successful utilization of the latent heat energy storage system depends considerably on the thermal reliability and stability of the phase change materials (PCMs) used. Thermal stability of phase change material can be established by measuring the thermo-physical properties of the PCM after a number of repeated thermal cycles. A comprehensive knowledge of thermal stability of the PCMs as functions of number of repeated thermal cycles is essential to ensure the long-term performance and economic feasibility of the latent heat storage systems. In this paper, a detailed review is reported for thermal stability of different groups of PCMs. The PCMs are categorized as organic (paraffins and non-paraffins), inorganic (salt hydrates and metallics) and eutectics (organic eutectics and inorganic eutectics). Further, a broad database of different PCMs is developed for which thermal cycling tests were carried out by different researchers and reported in the literature. The conclusions of the study were as follows. (1) The life span of the PCM depends on the thermal stability, chemical stability and corrosion resistance (containing material compatibility) after number of repeated, consistent thermal cycles. The most thermally stable PCM should have a negligible change in its latent heat and melting point. Hence it is always desirable to ensure thermal stability of PCM for long-term performance of the latent heat storage unit. (2) The most common method used by researchers to establish thermal properties of PCM, i.e. melting point and latent heat of fusion is the differential scanning calorimetry technique. As accurate information is of great importance for long-term performance of the storage unit, the effect of the temperature-dependent properties of prospective PCMs like, thermal conductivity, heat capacity and density should also be observed after repeated number of thermal cycles. The chemical stability of PCM after thermal cycling test was evaluated by Fourier transform infrared spectroscopy. The compatibility of the PCM with the PCM-containing materials can also be studied using scanning electron microscopy. (3) It is found that most organic and inorganic PCMs investigated in the literature are those whose melting temperature is in the range 30–60 °C and latent heat of fusion is in the range 150–250 kJ/kg. The most eutectic PCMs studied in literature has the melting point in the range 20–60 °C and latent heat of fusion is in the range 125–200 kJ/kg. (4) Most organic PCMs investigated are paraffins and fatty acids. It is found that paraffins have good thermal and chemical stability after number of thermal cycles. The fatty acids studied widely are stearic, lauric, myristic, capric and palmitic acid. Most of the fatty acids used as PCMs are industrial grade. As the thermal behaviour of industrial-grade PCMs may change, they should be subjected to an accelerated thermal test before the use. (5) Salt hydrates are the most studied inorganic PCMs. However, phase separation and supercooling are major problems in salt hydrates. These can be reduced to a certain extent by using gelled or thickened mixtures and using suitable nucleating materials, respectively. It is worth noting that calcium chloride hexahydrate ($CaCl_2 \cdot 6H_2O$) is the most widely analysed salt hydrate by many researchers. (6) An eutectic PCM is a combination of two or more compounds which are either organic, inorganic or both. In the past decade, many researchers have shown significant interest in new eutectic-type PCMs instead of pure compounds. It is observed that the most of the organic and inorganic eutectics which are proposed as PCMs are made from fatty acids and salt hydrates, respectively.

14/01015 Transient and quasi-steady thermal behaviour of a building envelope due to retrofitted cavity wall and ceiling insulation

Byrne, A. *et al. Energy and Buildings*, 2013, 61, 356–365.

Accurate understanding of the thermal behaviour of building components is essential for predicting heating or cooling needs and facilitates the implementation of more successful energy saving strategies and retrofits. This paper focuses on a specific measure commonly introduced through the residential energy efficiency retrofit programmes in Ireland – insulation. Traditionally, assessments of the performance of building envelopes have been based on assumed thermal resistances of the materials involved, laboratory tests and computer modelling. The aim of the present work is to investigate the *in situ* thermal behaviour of a case study building and its components under transient and quasi-steady environmental conditions, comparing data before and after the fixing of cavity wall and ceiling insulation. The paper concludes by proposing that predicted values of heat loss using standardized assumed material properties of the existing structure do not reflect the actual values achieved *in situ* for this test case. These values greatly overestimated the impact of the retrofitted insulation on heat loss through the ceiling and wall.

11 ENGINES

Power generation and propulsion, electrical vehicles

14/01016 An experimental investigation on fluid flow characteristics in a real coolant channel of LP turbine blade with PIV technique

Pu, J. *et al. Experimental Thermal and Fluid Science*, 2013, 45, 43–53.
Using a planar particle image velocimetry (PIV) system, the fluid flow characteristics including mean velocity and pressure fields in a real coolant channel of a low pressure (LP) turbine blade have been investigated. To understand the flow characteristics within the real LP turbine blade in detail, the studied channel has a real blade-similar cross section, and the entire channel consists of two dividing walls, three passes, a 180° bend, two tip exits and 25 trailing edge exits. At first, the flow structures in the channel are captured by the PIV system at an inlet Reynolds number of 44,000, when all the exits are open. The experimental results exhibit different secondary flow features from the previous investigations, which were conducted mostly in simplified two-pass square or rectangular channels. Secondly, through a statistical post-processing of measured instantaneous velocity fields, the Reynolds-averaged Navier–Stokes equations are solved to obtain the mean pressure distributions at several typical cross-sections. At last, the effects of the inlet Reynolds numbers and coolant ejection from the tip exit above the first pass on the flow characteristics are discussed. From the comparisons of the flow characteristics obtained at different flow conditions, it can be concluded that the flow characteristics are sensible to the inlet Reynolds number and coolant ejection from tip exit.

14/01017 Computational study of a new scheme for a film-cooling hole on convex surface of turbine blades

Yusop, N. M. *et al. International Communications in Heat and Mass Transfer*, 2013, 43, 90–99.
An investigation on a heart-shaped film cooling hole is performed for one row, two staggered rows, and three staggered rows on a convex surface. The results are compared with those obtained from a simple cylinder hole as a baseline. Three-dimensional computational study for two heart-shaped holes of two crown angles, $\varphi = 60°$ and $\varphi = 90°$, is conducted to ascertain adiabatic film cooling effectiveness to validate whether a heart-shaped cooling hole mitigates the vortexes responsible for the lift-off phenomenon in conventional simple cylinder hole. This paper also attempts to show that the staggered arrangement of a heart-shaped hole provides higher cooling performance. The result reveals that a heart-shaped hole highly mitigates the vortexes, thereby providing more coolant-surface attachment. The results reflect the tremendous increment in centreline and lateral adiabatic film cooling effectiveness for both crown angles, $\varphi = 60°$ and $\varphi = 90°$. The heart-shaped hole of crown angle $\varphi = 60°$ shows higher centreline effectiveness compared with that of the heart-shaped hole crown angle of $\varphi = 90°$. The latter provides higher lateral effectiveness. The relatively small volume and high effectiveness of the heart-shaped cooling hole is important and promising for the aero engine industry.

14/01018 Effect of lubricating oil on the particle size distribution and total number concentration in a diesel engine

Dong, L. *et al. Fuel Processing Technology*, 2013, 109, 78–83.
In this paper, the characteristics of particle size distribution in the exhaust gas of a diesel engine lubricated by two kinds of lubricating oil are investigated. The experiments are conducted in a turbocharged direct-injection diesel engine with a fast particulate spectrometer DMS 500 connected to the exhaust pipe. Two kinds of commonly used commercial lubricating oil, Kunlun API CF-4 15W40 and Mobil API CI-4 15W40, are chosen for the experiments. Particle size distribution and total number concentration are measured under medium load (100 N m) and full load. Barring a few exceptions, the results indicate that total particle number concentration is almost the same, while particle size distribution shows great difference.

14/01019 Effects of residual burnt gas heterogeneity on early flame propagation and on cyclic variability in spark-ignited engines

Pera, C. *et al. Combustion and Flame*, 2013, 160, (6), 1020–1032.
This paper investigates the effects of residual burnt gas (RBG) heterogeneity on premixed early flame propagation. The aim is to quantify the contribution of RBG spatial fluctuations on cycle-to-cycle variations (CCVs) observed in spark-ignited (SI) engines under stoichiometric operation. The authors performed direct numerical simulations (DNSs) of turbulent flame propagation with a semi-detailed kinetic mechanism for iso-octane (29 species and 48 reactions). To obtain relevant results for SI engines, aerothermochemical conditions (pressure, temperature, turbulence characteristics) representative of low-load engine operation were extracted from experimental data and engine large eddy simulation computations. The main findings are as follows. (1) RBG heterogeneity combines two opposing effects. Hot temperature pockets tend to locally increase the laminar flame speed, while diluted mixtures slow down flame propagation. (2) RBG heterogeneities locally enhance flame propagation because of the dominant effect of temperature over dilution. (3) RBG heterogeneities are able to create additional flame wrinkling even without the introduction of sensible enthalpy fluctuations. (4) DNS results contain valuable information to further the understanding of previously misinterpreted experimental observations in engines. The influence of RBG heterogeneities on the flame development process is minor compared to their contribution on heat release fluctuations and therefore on engine CCVs as a result of the non-linear chemical response to local mixture conditions.

14/01020 Fumigation of a heavy duty common rail marine diesel engine with ethanol–water mixtures

Goldsworthy, L. *Experimental Thermal and Fluid Science*, 2013, 47, 48–59.
A heavy duty common rail marine diesel engine operating with two stage injection is tested under load on a test bench with vaporized ethanol–water mixtures mixed into the inlet air at various rates. Ethanol/water mixture strengths of 93%, 72% and 45% by mass are tested. Results are presented for two engine loads at 1800 rpm, with a brake mean effective pressure (BMEP) of 17 and 20 bar. At each test point, constant engine speed and brake torque are maintained for various rates of aqueous ethanol addition. Small increases in brake thermal efficiency are measured with moderate rates of ethanol addition at a BMEP of 20 bar. Exhaust emissions of oxides of nitrogen, carbon monoxide, hydrocarbons, oxygen and carbon dioxide, and exhaust opacity are measured. Carbon monoxide emissions and exhaust opacity tend to increase with increased ethanol addition. NO_x emissions tend to decrease with increased ethanol addition and with increased water content. Hydrocarbon emissions remain low, near the detection limit of the analyser. Cylinder pressure and the electronically controlled two-stage liquid fuel injection timing are recorded with a high-speed data acquisition system. Apparent heat release rate is calculated from the measured cylinder pressure. The apparent heat release rate and fuel injection timing together allow analysis of the mechanism of the combustion process with ethanol fumigation. Two-stage injection involves a small pre-injection of diesel fuel to reduce early pressure rise rates in normal diesel engine combustion. Even though injection timing is retarded by the engine control unit as more ethanol is added, combustion timing effectively advances due to the effect of two stage injection. Where the ethanol–air mixture strength is above the lower flammability limit at compression temperatures, the mixture is ignited by the pre-injection and begins to burn rapidly by flame propagation and/or autoignitive propagation before the main liquid fuel injection begins. This occurs for ethanol energy substitution rates greater than 30%. Two distinct peaks in heat release rate appear at the higher ethanol rates. Severe knock becomes apparent for 34% ethanol. Two-stage injection may be disadvantageous in these circumstances.

14/01021 Fundamental phenomena affecting low temperature combustion and HCCI engines, high load limits and strategies for extending these limits

Saxena, S. and Bedoya, I. V. *Progress in Energy and Combustion Science*, 2013, 39, (5), 457–488.
Low temperature combustion (LTC) engines are an emerging engine technology that offers an alternative to spark-ignited and diesel engines. One type of LTC engine, the homogeneous charge compression ignition (HCCI) engine, uses a well-mixed fuel–air charge like spark-ignited engines and relies on compression ignition like diesel engines. Similar to diesel engines, the use of high compression ratios and removal of the throttling valve in HCCI allow for high efficiency operation, thereby allowing lower CO_2 emissions per unit of work delivered by the engine. The use of a highly diluted well-mixed fuel–air charge allows for low emissions of nitrogen oxides, soot and particulate matters, and the use of oxidation catalysts can allow low emissions of unburned hydrocarbons and carbon monoxide. As a result, HCCI offers the ability to achieve high efficiencies comparable with diesel while also allowing clean emissions while using relatively inexpensive after-treatment technologies. HCCI is not, however, without its challenges. Traditionally, two important problems prohibiting market penetration of HCCI are (1) inability to achieve high load, and (2) difficulty in controlling combustion timing. Recent research has significantly mitigated these challenges, and thus HCCI has a promising future for automotive and power generation applications. This article begins by providing a comprehensive review of the physical

phenomena governing HCCI operation, with particular emphasis on high load conditions. Emissions characteristics are then discussed, with suggestions on how to inexpensively enable low emissions of all regulated emissions. The operating limits that govern the high load conditions are discussed in detail, and finally a review of recent research which expands the high load limits of HCCI is discussed. Although this paper focuses on the fundamental phenomena governing HCCI operation, it is also useful for understanding the fundamental phenomena in reactivity controlled compression ignition, partial fuel stratification, partially premixed compression ignition, spark-assisted HCCI, and all forms of low temperature combustion.

14/01022 Performance evaluation and experiment system for waste heat recovery of diesel engine

Gao, W. *et al. Energy*, 2013, 55, 226–235.

In this paper, a waste heat recovery system is proposed where a high speed turbocharged diesel engine acts as the topper of a combined cycle with exhaust gases used for a bottoming Rankine cycle. The paper describes a mathematical model to evaluate the performance of Rankine cycle system with a reciprocating piston expander. The paper focuses on the performance evaluation and parameter selection of the heat exchanger and reciprocating piston expander that are suitable for waste heat recovery of an internal combustion engine (ICE). The paper also describes the experimental setup and the preliminary results. The simulation results show that a proper intake pressure should be 4–5 MPa at its given mass flow rate of 0.015–0.021 kg/s depending on the waste heat recovery of a turbocharged diesel engine (80 kW/2590 rpm). The net power and net power rise rate at various ICE rotation speeds are calculated. The result shows that introducing heat recovery system can increase the engine power output by 12%, when diesel engine operates at 80 kW/2590 rpm. The preliminary experimental results indirectly prove the simulation model by two negative work loops in the *P–V* curve, under a low intake pressure and steam flow rate condition.

14/01023 Rotor demagnetization effects on permanent magnet synchronous machines

Ruschetti, C. *et al. Energy Conversion and Management*, 2013, 74, 1–8.

The effects of asymmetrical magnet faults on the rotor of permanent magnet synchronous machines (PMSM) are analysed in this study. Two different stator winding configurations, series and parallel connected windings, are considered in the analysis. From PMSM with parallel windings, a fault detection strategy based on the information contained in the branch-current spectrum is proposed. A fault severity factor is defined to quantify demagnetization on a single magnet. This factor is practically independent from the motor load conditions. Simulation results using a finite element model are obtained to evaluate the feasibility of the proposal. Additionally, voltage reduction and current derating due to rotor demagnetization are also evaluated. Experimental results are presented to validate the proposal.

14/01024 The pulse tube engine: a numerical and experimental approach on its design, performance, and operating conditions

Moldenhauer, S. *et al. Energy*, 2013, 55, 703–715.

The pulse tube engine is a simple heat engine based on the pulse tube process. Due to its simplicity it has a high potential to be applicable in waste heat usage and energy harvesting purposes. This study clarifies the working principle of the pulse tube engine and shows its potential and limitations. The developed numerical and experimental tools could be used successfully to build up a pressurized working engine and characterize its mode of operation under different heat input temperatures, filling pressures and operating frequencies. Model and experiment deliver comparable engine performances. The theoretical disadvantage of the pulse tube engine process based on an intrinsically irreversible thermodynamic cycle could be compensated by its practical advantages, such as a comparably low flow friction power loss and the simple mechanical gear system associated with its low production costs.

Hybrid engine systems

14/01025 An experimental investigation of performance-emission trade off of a CI engine fueled by diesel–compressed natural gas (CNG) combination and diesel–ethanol blends with CNG enrichment

Paul, A. *et al. Energy*, 2013, 55, 787–802.

In order to comply with the ever-stringent emission norms throughout the world and crunch in petroleum reserves, the modern day automobile industry is compelled to hunt for new and alternative means of fuel sources to keep the wheels spinning globally. Paradoxical objectives of attaining simultaneous reduction in emission along with high performance has provided with a few alternatives. The present study deals with one such approach in which the potential of diesel ethanol blending and subsequent compressed natural gas (CNG) enrichment have been investigated. The study starts with a miscibility test of ethanol in diesel, which paves the way for an experimental comparison between performance and emission characteristics of diesel–ethanol blends, diesel–CNG combinations and diesel–ethanol blends with CNG enrichment. The results indicates that diesel ethanol blend D95E5 (95% diesel, 5% ethanol) with low CNG enrichment produces a better performance-emission characteristics as compared to base diesel operation as well as diesel–ethanol blend operation. Results also portrayed ethanol's potential in reducing NO_x emission, brake specific energy consumption and smoke opacity.

14/01026 Comparative analysis of engine generator performance using diesel oil and biodiesels available in Paraná State, Brazil

da Silva, M. J. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 278–282.

Biodiesel is an alternative energy source used in internal combustion engines (ICE), as a replacement for diesel oil. In general, the farming and livestock activities can be used to obtain biomass sources for bioenergy production. Several raw materials (fatty acid sources) obtained from renewable sources can be employed to biodiesel production, providing biofuels with distinct physicochemical properties. Also, in Paraná state, Brazil, products such as soybean oil, sunflower oil, beef tallow, and chicken fat are used for biodiesel manufacturing. Thus, this work aimed to evaluate the engine generator performance using biodiesels obtained from soybean, sunflower, chicken fat and beef tallow compared to mineral diesel. The tests were performed using an engine with power of 7.36 kW on an electric generator with power of 5.5 kW. In engine load simulation, it was used as resistor bank, being the power generation selected on dashboard controller in the following sequences: 1.0, 2.0, 3.0 and 4.0 kW. The engine generator performance was evaluated by specific fuel consumption (SFC) and efficiency (η). In general, the engine SFC using biodiesels was higher, when compared to diesel oil. However, the overall efficiency of engine generator with biodiesels was higher, with gain of up to 2.0%. Among the biodiesels compared to diesel oil, the best results for engine generator performance were obtained, respectively, from sunflower and soybean oils, due to lower increase in the SFC (7.6%) and slight increase in the overall efficiency.

14/01027 Comparative evaluation of emission and fuel economy of an automotive spark ignition vehicle fuelled with methane enriched biogas and CNG using chassis dynamometer

Subramanian, K. A. *et al. Applied Energy*, 2013, 105, 17–29.

The fuel economy and mass emission of an automotive spark ignition vehicle fuelled with the methane-enriched biogas (93% CH_4) and base compressed natural gas (CNG) (89.14%) were evaluated using chassis dynamometer under modified Indian driving cycle. The transient emissions were also measured with respect to time. The emissions such as CO, HC and NO_x are marginally higher with the enriched biogas than base CNG. But, the experimental results indicate that the vehicle's emission with the enriched biogas fuel meets to the BS IV emission norms. There is no significant change in fuel economy of the vehicle fuelled with the enriched biogas (24.11 km/kg) as compared to base CNG (24.38 km/kg). The experimental data indicates transient emission characteristics (CO, HC and NO_x) of the vehicle with respect to time for both fuels are very higher with urban cycle (low speed) than extra urban cycle (high speed) and the findings could be useful to find out scopes of further improvement in transient emission and performance of the engine. As the methane-enriched biogas gives a similar performance to fossil CNG, the enriched biogas could be used as an auto fuel for spark ignition vehicles.

14/01028 Conditional-logit Bayes estimators for consumer valuation of electric vehicle driving range

Daziano, R. A. *Resource and Energy Economics*, 2013, 35, (3), 429–450.

Range anxiety – consumers' concerns about limited driving range – is generally considered an important barrier to the adoption of electric vehicles. If consumers cannot overcome these fears it is unlikely that they will consider purchasing an electric car. Hence, a successful introduction of low emission vehicles in the market requires a full understanding of consumer valuation of driving range. By analysing experimental data on vehicle purchase decisions in California, the author derived and studied the statistical behaviour of Bayes estimates that summarize consumer concerns toward limited driving range. These estimates are superior to marginal utilities as parameters of interest in a discrete demand model of vehicle choice. One of the empirical results is the posterior distribution of the willingness to pay for electric vehicles with improved batteries offering better driving range. Credible intervals for this willingness to pay, as well as both parametric and nonparametric heterogeneity distributions, are also analysed.

14/01029 Economics and greenhouse gas balance of biogas use systems in the Finnish transportation sector

Uusitalo, V. *et al. Renewable Energy*, 2013, 51, 132–140.

Energy decisions play an essential role in reducing greenhouse gas (GHG) emissions in the transportation sector. Biogas is a renewable energy source and can be used as an energy source for gas-operated cars or for electric cars. This paper compares different ways to use biogas, which is produced on a medium scale anaerobic digestion plants, as an energy source for transportation. The research is conducted from an economic and environmental point of view, and the option to deliver upgraded biogas via a natural gas grid is taken into account. Different processes for the use of biogas for transportation purposes are compared using life cycle assessment methods in the Finnish operational environment. It seems that the most economical way is to use biogas in gas-operated cars due to the high price of methane for vehicle fuel use. A new feed-in tariff for electricity produced with biogas will, however, have highly positive economic effects on electricity production from biogas. From the environmental point of view, the highest CO_2 reductions are gained when biogas is used in gas-operated cars or in combined heat and power plants for power and heat production. During the transition stage, it might be reasonable to use biogas in gas-operated cars and most importantly in heavy vehicles to reduce GHG and local pollutants rapidly. If biogas production is located near a natural gas grid, the biogas can be delivered effectively via the natural gas grid. The use of biogas in gas-operated cars is an effective way to reduce carbon dioxide significantly in the transportation sector.

14/01030 Exhaust emissions with ethanol or *n*-butanol diesel fuel blends during transient operation: a review

Giakoumis, E. G. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 170–190.

This study reviews the literature concerning the effects of alcohol/diesel blends on the exhaust emissions of diesel engines operating under transient conditions, i.e. acceleration, load increase, starting and transient/driving cycles. Two very promising alcohols are covered in this survey, namely ethanol and *n*-butanol. The analysis focuses on all regulated exhaust pollutants, i.e. particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO) and unburned hydrocarbons (HC), with results for unregulated emissions, carbon dioxide and combustion noise radiation also included. The main mechanisms of exhaust emissions during transients are identified and discussed, with respect to the fundamental aspects of transient operation and the differing properties of alcohols relative to the reference diesel oil. Based on the published studies up today, summarization of emissions data and cumulative trends are presented, for the purpose of quantifying the alcohol blends benefits or penalties on the regulated emissions during various driving cycles. Particularly for the emitted PM and smoke, a statistically significant correlation with the oxygen content exists ($R^2 = 0.85$ and 0.95, respectively). A similar correlation holds true for the heavy-duty, engine-dynamometer data of engine-out CO. Finally, a detailed list is provided that summarizes the main data from all studies published so far.

14/01031 Life-cycle private costs of hybrid electric vehicles in the current Chinese market

Lin, C. *et al. Energy Policy*, 2013, 55, 501–510.

Understanding the life-cycle private cost (LCPC) of the hybrid electric vehicle (HEV) is important for market feasibility analysis. An HEV LCPC model was established to evaluate HEV market prospects in China compared with traditional internal combustion engine vehicles (ICEV). The Kluger HV, a full-hybrid HEV sports utility vehicle (SUV), aimed at the Chinese market, was simulated as the 2010 model's technology details were well publicized. The LCPC of the Kluger HV was roughly the same (about 1.06 times) as that of its comparable ICEV (Highlander SUV). This aligns with other compact and midsize HEV cars (e.g. Toyota Prius, Honda Civic and Toyota Camry HEV) in China. With oil prices predicted to rise in the long term, the advantage of HEVs energy saving will partly compensate the high manufacturing costs associated with their additional motor/battery components. Besides supporting technology development, enabling policy should be implemented to introduce HEV technology into taxi fleets and business cars. This technology's cost-competitiveness, compared with traditional ICEVs, is advantageous for these higher mileage vehicles.

14/01032 Performance and NO_x emissions of a diesel engine fueled with biodiesel-diesel-water nanoemulsions

Koc, A. B. and Abdullah, M. *Fuel Processing Technology*, 2013, 109, 70–77.

The purpose of this research was to investigate the effects of water concentration in a biodiesel nanoemulsion fuel on engine performance and exhaust emissions of a four-cylinder diesel engine. Biodiesel nanoemulsions containing 5%, 10% and 15% water were used for the engine tests and the results were compared with B5, B20 and certified #2 diesel fuels. Biodiesel nanoemulsions produced lower NO_x emissions and soot opacity than B5, B20 and certified #2 diesel fuels. Biodiesel nanoemulsion with 5% water concentration produced engine power and torque values that were similar to the values measured for B5 fuel. Increasing water concentrations in biodiesel nanoemulsions increased the engine brake specific fuel consumption and CO emissions. The rate of NO_x reduction was greater than the rate of CO increase when the water concentration in biodiesel nanoemulsions increased from 10% to 15%. These results provided strong evidences on the effects of increasing water concentration in biodiesel emulsions on reducing NO_x and soot from a four-cylinder diesel engine. Emulsified biodiesel fuel is a promising alternative method for reducing harmful emissions from diesel engines without requiring significant engine modifications.

14/01033 Sewage sludge producer gas enriched with methane as a fuel to a spark ignited engine

Szwaja, S. *et al. Fuel Processing Technology*, 2013, 110, 160–166.

The paper presents results and discussion on syngas combustion in a spark-ignited internal combustion engine driving a power generator (16 kW/1500 rpm). The syngas applied as the engine fuel is produced by gasifying municipal sewage sludge. Unlike fermentation biogas, the syngas obtained from sewage sludge gasification is found a fuel, which generates several difficulties (non-stable combustion, misfiring events) while burning in the SI engine. The analysis of cycle-by-cycle engine run shows that the engine working on syngas features will run unsteadily due to the occurrence of misfiring events caused by the relatively low calorific value of the syngas. Thus, combustion of such a syngas in the spark-ignited internal combustion engine can generate malfunctions. Therefore, the syngas was enriched with methane at various ratios starting from 0% up to 60% by volume. The impact of methane addition on the engine performance and exhaust emission was also presented in the paper. As investigated, 40% methane enrichment in the syngas was found sufficient amounts to obtain satisfactory engine run. Thus, in practice, the syngas from sewage sludge gasification is a troublesome fuel, but can satisfactorily be applied to the spark-ignition engine when enriched with natural gas or biogas.

14/01034 The effect of combustion chamber geometry on injection and mixture preparation in a CNG direct injection SI engine

Yadollahi, B. and Boroomand, M. *Fuel*, 2013, 107, 52–62.

In pursuing a project to convert a four-cylinder gasoline multi-point port fuel injection engine to a compressed natural gas (CNG) direct injection engine, a numerical model has been developed in AVL FIRE software to undertake a detailed numerical investigation on the effects of combustion chamber geometry in such engines. Two main phases have been considered in the present study. In the first phase, aiming to fully investigate flow field and mixing process, multi-dimensional numerical modelling of transient gas injection has been performed. In order to verify the accuracy of the model, two different validation cases have been employed. The results showed that the models are quite capable of grasping all the significant physical phenomena in the process. Adoption of such a modelling was found to be a challenging task because of required computational effort and numerical instabilities. In all validation cases, experimental and numerical results were observed to have excellent agreement with each other. In the second phase, using the moving mesh capability the validated model has been developed to include methane direct injection into the cylinder of a direct injection engine for various combustion chamber geometries. Five different piston head shapes along with two injector types of single hole and multi hole have been taken into consideration. A centrally mounted injector location has been adapted to all cases. The effects of combustion chamber geometry, injection parameters, injector type and cylinder head shape have been studied on mixing of air–fuel inside cylinder. Based on the results, suitable geometrical configuration for the new natural gas direct injection engine has been discussed.

Transport battery development

14/01035 A multi-level energy management system for multi-source electric vehicles – an integrated rule-based meta-heuristic approach

Trovão, J. P. *et al. Applied Energy*, 2013, 105, 304–318.

In this paper, an integrated rule-based meta-heuristic optimization approach is used to deal with a multi-level energy management system for a multi-source electric vehicle for sharing energy and power between two sources with different characteristics, namely one with high specific energy (battery) and other with high specific power (SuperCapacitors). A first (long-term) management level dynamically restricts the search space based on a set of rules (strategic decisions). A second (short-term) management level implements the optimization strategy based on a meta-heuristic technique (tactical decisions). The solutions to the optimal power sharing problem are be used to generate the power references for a lower (operational) level DC–DC converters controller. The simulated annealing meta-heuristic is used to define an optimized energy and power share without prior knowledge of power demand. The proposed scheme has been simulated in Matlab®, with models of energy sources for several driving cycles. Illustrative results show the effectiveness of this multi-level energy management system allowing to fulfill the requested performance with better source usage and much lower installed capacities.

14/01036 A review on the key issues for lithium-ion battery management in electric vehicles

Lu, L. *et al. Journal of Power Sources*, 2013, 226, 272–288.

Compared with other commonly used batteries, lithium-ion batteries are featured by high-energy density, high power density, long service life and environmental friendliness and thus have found wide application in the area of consumer electronics. However, lithium-ion batteries for vehicles have high capacity and large serial-parallel numbers, which, coupled with such problems as safety, durability, uniformity and cost, imposes limitations on the wide application of lithium-ion batteries in the vehicle. The narrow area in which lithium-ion batteries operate with safety and reliability necessitates the effective control and management of battery management system. This paper, through the analysis of literature and in combination with the practical experience, gives a brief introduction to the composition of the battery management system and its key issues such as battery cell voltage measurement, battery states estimation, battery uniformity and equalization, battery fault diagnosis and so on, in the hope of providing some inspirations to the design and research of the battery management system.

14/01037 An improved control method of battery energy storage system for hourly dispatch of photovoltaic power sources

Daud, M. Z. *et al. Energy Conversion and Management*, 2013, 73, 256–270.

The effects of intermittent cloud and changes in temperature cause a randomly fluctuated output of a photovoltaic (PV) system. To mitigate the PV system impacts particularly on a weak electricity network, battery energy storage (BES) system is an effective means to smooth out the power fluctuations. Consequently, the net power injected to the electricity grid by PV and BES (PV/BES) systems can be dispatched smoothly such as on an hourly basis. This paper presents an improved control strategy for a grid-connected hybrid PV/BES systems for mitigating PV farm output power fluctuations. A feedback controller for BES state of charge is proposed, where the control parameters are optimized using genetic algorithm (GA). GA-based multi-objective optimization utilizes the daily average PV farm output power profile which was obtained from simulation using the historical PV system input data of Malaysia. In this way, the optimal size for the BES is also determined to hourly dispatch a 1.2 MW PV farm. A case study for Malaysia is carried out to evaluate the effectiveness of the proposed control scheme using PSCAD/EMTDC software package. Furthermore, the validation of results of the proposed controller and BES size on the actual PV system output data are also given. Finally, a simple payback calculation is presented to study the economic aspects of the BES investment on the proposed mitigation strategy under Malaysian feed-in tariff programme.

14/01038 Efficient and lightweight battery management system contributes to victory in the Green Flight Challenge 2011

Tomažič, J. and Žemva, A. *Electric Power Systems Research*, 2013, 98, 70–76.

Electric-powered aircraft has been designed and flown for quite a while. However, until 2011 all the existing models had one major drawback, namely, a low range caused by the low energy capacity of the batteries. Besides the motor and motor controller, the battery system is one of the most critical components of the electric aircraft. Lightweight, high efficiency and high reliability are only a few challenges in the design process. The paper describes the battery system and a new active battery balancing method used for the Taurus G4 of the Pipistrel manufacture, the world's first four-seat electric aircraft, that won the 2011 Green Flight Challenge competition for being the most energy efficient aircraft ever built.

14/01039 Highly reversible lithium storage in uniform $Li_4Ti_5O_{12}$/carbon hybrid nanowebs as anode material for lithium-ion batteries

Yang, Z. *et al. Energy*, 2013, 55, 925–932.

Very large area, uniform $Li_4Ti_5O_{12}$/carbon composite nanowebs consisting of interconnected nanofibres were synthesized by a simple method based on thermal pyrolysis and oxidation of a composite of electrospun lithium–titanium/polyacrylonitrile nanowebs in argon atmosphere. This novel composite is characterized by the encapsulation of highly uniform nanoscale $Li_4Ti_5O_{12}$ crystals in the porous cotton-like carbon matrix. This unique structure, consisting of ultra-small crystals in carbon core/shell architecture, is also characterized by high porosity, with many nanopores and mesopores in the composite, and this, together with the high conductive carbon matrix, would facilitate the excellent electrochemical performance of $Li_4Ti_5O_{12}$/carbon composite nanoweb electrode. The $Li_4Ti_5O_{12}$/carbon hybrid nanoweb electrodes display a reversible capacity of approximately 160.8 $mAhg^{-1}$ at a current density of 30 mAg^{-1} and excellent cycling stability. The $Li_4Ti_5O_{12}$/carbon hybrid nanoweb electrodes also exhibit excellent rate performance, delivering a discharge capacity of over 87 $mAhg^{-1}$ at a current density of 3000 mAg^{-1}. These results indicate that the composite is a promising anode candidate for lithium ion batteries.

14/01040 $LiFePO_4$ battery pack capacity estimation for electric vehicles based on charging cell voltage curve transformation

Zheng, Y. *et al. Journal of Power Sources*, 2013, 226, 33–41.

Because of the diversiform driving conditions and the cell variations, it is difficult to accurately determine battery pack capacities in electric vehicles (EVs) by model prediction or direct measurement. This paper studies the charging cell voltage curves (CCVC) for the estimation of the $LiFePO_4$ battery pack capacities in EVs. The authors propose the uniform CCVC hypothesis and estimate cell capacities by overlapping CCVCs using CCVC transformation. CCVCs of two $LiFePO_4$ cells with large capacity difference are used to verify the hypothesis. They further develop an equivalent simplified approach using voltage-capacity rate curve (VCRC) and implement genetic algorithm (GA) to find the optimum transformation parameter for overlapping VCRCs. A small battery pack with four $LiFePO_4$ cells in series is employed to verify the method and the result shows that the estimation errors of both pack capacity and cell capacities are less than 1%. With the proposed method, the battery pack capacity can be precisely estimated which could be used for the driving range prediction. Meanwhile, the estimated cell capacities in battery packs will significantly support the study of cell degradation and cell variations in vehicle driving conditions.

14/01041 Modeling the impact of electric vehicle charging on heat transfer around underground cables

Marshall, J. S. *et al. Electric Power Systems Research*, 2013, 97, 76–83.

While the increasing use of plug-in electric vehicles (PEVs) has environmental and economic benefits, the increased load is expected to strain components of the power delivery infrastructure. Within electric distribution systems, overloading of transformers and underground cables and associated thermal degradation is of particular concern. This paper estimates the effect of different levels and types of PEV charging on transient heating of underground cables. Transportation survey data are used to estimate travel miles and arrival/departure times for a typical residential neighbourhood, which is subsequently used to estimate the electric load curve with different levels of PEV penetration. The estimated load curves are used to perform transient heat transfer computations for a system of three buried cables using an overset grid finite-difference approach, the results of which are used to estimate acceleration of cable thermal degradation. Vehicle charging, even for a modest 30% PEV penetration, is found to nearly double peak temperature rise above ambient at the cable surface, increase the daily variance in cable temperatures, and significantly decrease the estimated time to failure for cables with thermally sensitive insulation.

14/01042 Numerical investigations of flow field designs for vanadium redox flow batteries

Xu, Q. *et al. Applied Energy*, 2013, 105, 47–56.

As a key component of flow batteries, the flow field is to distribute electrolytes and to apply/collect electric current to/from cells. The critical issue of the flow field design is how to minimize the mass transport polarization at a minimum pressure drop. In this work a three-dimensional numerical model is proposed and applied to the study of flow field designs for a vanadium redox flow battery (VRFB). The performance of three VRFBs with no flow field and with serpentine and parallel flow fields is numerically tested. Results show that when a flow field is included a reduction in overpotentials depends not only on whether a flow field can ensure a more even distribution of electrolytes over the electrode surface, but also on whether the flow field can facilitate the transport of electrolytes from the flow field towards the membrane, improving the distribution uniformity in the through-plane direction. It is also shown that the pumping power varies with the selection of flow fields at a given flow rate. To assess the suitability of flow fields, a power-based efficiency, which takes account of both the cell performance and pumping power, is defined and calculated for different flow fields at different electrolyte flow rates. Results indicate that there is an optimal flow rate for each type of flow field at which the maximum efficiency can be achieved. As the cell with the serpentine flow field at the optimal flow rate shows the highest energy-based efficiency and round-trip efficiency, this type of flow field appears to be more suitable for VRFBs than the parallel flow field does.

14/01043 Optimal plug-in hybrid electric vehicles recharge in distribution power systems

Oliveira, D. Q. *et al. Electric Power Systems Research*, 2013, 98, 77–85.
Plug-in hybrid electric vehicles are new alternatives that meet the efforts to develop more sustainable means of transportation and decreasing oil dependence. However, this trend could bring negative consequences to electric power systems, such as limits violations, power losses increasing, harmonics, and thermal limits violation on distribution transformers and conductors. To cope with some of those problems, this paper proposes a recharging process with the help of artificial immune systems, so the voltage level in all buses is kept within the operational limits and no overload is observed. For this sake, besides distributing the load along the recharging period, capacitors installation to decrease electric losses and improve voltage levels during vehicles recharging is also considered. The results obtained render the proposed methodology as effective. Two IEEE sample systems are used to test the idea, so the results may be reproduced for research purposes.

14/01044 Performance of an all-electric vehicle under UN ECE R101 test conditions: a feasibility study for the city of Kaunas, Lithuania

Raslavičius, L. *et al. Energy*, 2013, 55, 436–448.
Transport activity has been a key facilitator and driver of economic prosperity in Lithuania and it is likely to continue to grow. It can produce both positive and negative effects on the quality of life and the environment depending on country-specific circumstances. This research paper sets the stage for a look at the Lithuanian passenger vehicle fleet and its transition towards sustainable mobility through the use of all-electric vehicles. The Renault Espace, a large multipurpose vehicle, was used for test drives, according ECE R101 (urban cycle) requirements. The conventional spark-ignited internal combustion engine of the vehicle was replaced by the electric one and equipped with the new generation LiFePO$_4$ lithium-ion rechargeable batteries. Three streets of Kaunas city with different categories B1, B2 and C2 were selected for the test procedure. Estimation of the power demand (depending on displacement and daytime) and evaluation of battery performance characteristics were discussed in detail. Calculation of the driving distance of the one charge of the traction battery estimates several driving conditions and variation of the mass of the investigated vehicle. Comparison of consumption of different fuel grades for 1 km showed that costs of electric power driven vehicle is four times as low as with A95 grade petrol and 2.4 times as low as with diesel fuel.

14/01045 Resonant photoemission spectroscopy of the cathode material Li$_x$Mn$_{0.5}$Fe$_{0.5}$PO$_4$ for lithium-ion battery

Kurosumi, S. *et al. Journal of Power Sources*, 2013, 226, 42–46.
This study investigated the change in the electronic structure of Li$_x$Mn$_{0.5}$Fe$_{0.5}$PO$_4$ through the charge process, especially in the transition metal partial DOS using X-ray absorption and resonant photoemission spectroscopy measurements. The oxidation reaction between Fe^{2+} and Fe^{3+} proceeds while the 0.5 Li ions are extracted from LiMn$_{0.5}$Fe$_{0.5}$PO$_4$. Moreover, comparing resonant photoemission spectra of Li$_x$Mn$_{0.5}$Fe$_{0.5}$PO$_4$ with those of Li$_x$FePO$_4$, the authors found that both spectral line-shapes are almost identical, suggesting that the strong localization of the Fe 3*d* states in the LiMn$_{0.5}$Fe$_{0.5}$PO$_4$ system. On the other hand, in Mn 2*p*–3*d* X-ray absorption and resonant photoemission spectra, the Mn oxidation reaction from Mn^{2+} to Mn^{3+} partially occurs and Mn 3*d* states of Li$_x$Mn$_{0.5}$Fe$_{0.5}$PO$_4$ remain almost unchanged through the charge reaction. Reflecting the difference in the strength of the interaction between the transition metal Fe or Mn ions and the oxygen ions, it is suggested that although the oxidation from Fe^{2+} to Fe^{3+} proceeds largely on Fe ions during the charge reaction from $x = 1.0$ to 0.5, the charge compensation for the electron exchange mainly occurs not only at the Mn ions but also at the poly-anion sites during the charge reaction from $x = 0.5$ to 0.

14/01046 Surface and structural stabilities of carbon additives in high voltage lithium ion batteries

Zheng, J. *et al. Journal of Power Sources*, 2013, 227, 211–217.
The stabilities of different conductive carbon additives have been systematically investigated in high voltage lithium ion batteries. It is found that the higher surface area of conductive additives leads to more parasitic reactions initiating from different onset voltages. A closer inspection reveals that for the low surface area carbon such as Super P, PF$_6^-$ anions reversibly intercalate into carbon structure at around 4.7 V. For high surface area carbons, in addition to the electrolyte decomposition, the oxidation of functional groups at high voltage further increases the irreversible capacity and Li$^+$ ion consumption. Coulombic efficiency, irreversible capacity and cycling stability observed by using different carbon additives are correlated with their structure and surface chemistry, thus providing information for predictive selection of carbon additives in different energy storage systems.

14/01047 The impact of federal incentives on the adoption of hybrid electric vehicles in the United States

Jenn, A. *et al. Energy Economics*, 2013, 40, 936–942.
Starting in 2004, the federal government in the USA offered several nationwide incentives to consumers to increase the adoption of hybrid electric vehicles. This study assesses the effectiveness of the 2005 Energy Policy Act in this regard using econometric methods and data between 2000 and 2010. The model accounts for network externalities by using lagged sales as an independent variable. This approach helps to capture the exponential initial growth associated with the diffusion of new technologies and avoids overestimating the effect of the policy incentives. The results show that the 2005 Energy Policy Act increased the sales of hybrids from 3% to 20% depending on the vehicle model considered. In addition, the authors found that this incentive is only effective when the amount provided is sufficiently large.

14/01048 The optimal subsidy on electric vehicles in German metropolitan areas: a spatial general equilibrium analysis

Hirte, G. and Tscharaktschiew, S. *Energy Economics*, 2013, 40, 515–528.
E-mobility and diffusion of electric vehicles have become a major policy issue in many countries. For example, the German federal government pursues the strategy of achieving one million electric vehicles by 2020. This study examines whether it is optimal to subsidize the use of electric vehicles by granting electric power subsidies and how large the corresponding optimal rate is. The authors, first, analytically derive the optimal power tax in a spatial model of a city with two zones where commuting, carbon emissions, endogenous labour supply, fuel and power taxes are considered. It is shown that in a spatial urban environment, the optimal tax rate depends in particular on transport related externalities, tax interaction effects and redistribution effects working via the urban land market. Second, the authors extend the model to a full spatial general equilibrium model and employ simulations to calculate sign and size of the optimal tax/subsidy rate. This model is calibrated to a typical German metropolitan area. The results show that electric vehicles should not be subsidized but taxed. The results are robust with respect to changes in the willingness to adopt electric vehicles, the costs of driving electric vehicles, and even if emissions of electric vehicles are zero.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

14/01049 A generalized method of estimation of critical exponents through an indigenous susceptometry setup for YBCO materials

Chakrabarti, A. and Neogy, C. *Cryogenics*, 2013, 55–56, 35–46.
The real and imaginary parts of complex susceptibility values of bulk ceramic yttrium barium copper oxide (YBCO) materials have been extracted at different frequencies and temperatures by measuring impedances using a single-coil swept-ac method. From these susceptibility components, the ac conductivity and its loss angle have been derived numerically. The dynamic and static critical exponents obtained from the scaling of conductivity loss angle based on Fisher, Fisher and Huse's vortex glass (VG) model were found to be in agreement with the values obtained by other workers, in different methods characterizing a continuous phase transition and revealing a stronger correlation in high-temperature superconductivity materials. To verify their universality, it has been shown that the exponent values support the scaling features of ac-conductivity (or resistivity) very well and can scale susceptibility also at the proximity of critical temperature. It is expected that this simpler and straightforward method of extraction and evaluation of these critical exponents discussed here may be applicable to any other high temperature superconductors or other complex materials in bulk form.

14/01050 A unit cell approach to compute thermal conductivity of uncured silicone/phosphor composites

Yuan, C. and Luo, X. *International Journal of Heat and Mass Transfer*, 2013, 56, (1–2), 206–211.

Composites of silicone matrix filled with phosphor are widely used in light emitting diodes (LEDs) packaging. Its thermal conductivity is one of the important properties for LED thermal analysis. In this paper, a unit cell model (UCM) that includes interface resistance between phosphor and silicone matrix was built and applied to predict the thermal conductivity of uncured silicone/phosphor composites at different phosphor volume fractions. The thermal conductivities of seven uncured silicone/phosphor composites samples were measured for comparison with modelling results. The comparison shows that the model result matches to the experimental data within $\pm 6\%$ at the low volume fraction from 3.8% to 25%. Both the experiment and modelling results show that thermal conductivity of the composite has a sudden increase when volume fraction increases to near 40%, which can be explained by the percolation theory. For higher volume fraction, the effect of the interface resistance R_b between the phosphor fillers and silicone matrix cannot be neglected.

14/01051 Carboxylic acid removal from model petroleum fractions by a commercial clay adsorbent

Silva, J. P. *et al. Fuel Processing Technology*, 2013, 112, 57–63.

This work investigates the use of a commercial clay adsorbent for removing carboxylic acids from model petroleum fractions. The main objective is to emulate the corresponding removal of naphthenic acids from real petroleum fractions. The bulk properties of the adsorbent were analysed by several physicochemical techniques. The adsorbent capacity of removing three different carboxylic acids was evaluated by conducting equilibrium and kinetics studies in batch systems. A comparison of the performances of different isotherm models indicated that the Brunauer, Emmett and Teller isotherm is the most adequate model to represent the adsorption equilibrium. A kinetic model using mass balances in the solid and fluid phases presented a good match with the experimental data. The equilibrium results of a model sample were also compared to the removal of naphthenic acids from a real petroleum cut.

14/01052 Effect of the drilling process on the compression behavior of glass/epoxy laminates

Karimi, N. Z. *et al. Composite Structures*, 2013, 98, 59–68.

Composite materials have been widely used in various industries due to their superior mechanical properties. Drilling is a very common machining operation to install fasteners for assembly of laminates. Delamination, however, is a serious concern in the drilling of fibre-reinforced composite materials, because it reduces their compressive residual strength. This paper studies the effects of drilling parameters on the thrust force, adjusted delamination factor and compressive residual strength of unidirectional glass/epoxy resin. The design of the experiment was based on the Taguchi method. The results highlight the importance of the feed rate for maximizing the compressive residual strength of drilled laminates. The acoustic emission (AE) technique was also used to monitor both drilling process and compression test. The objective was to establish a correlation between AE parameters and mechanical characteristics. The results reveal that root mean square (RMS) can be used for monitoring thrust force and AE energy for compression force.

14/01053 Enhanced electrical conductivity of $La_2Mo_{1.4}W_{0.6}O_9$ ceramic prepared by laser rapid solidification method

Yu, J. *et al. Journal of Power Sources*, 2013, 226, 334–339.

A new method, laser rapid solidification, has been employed to prepare a kind of oxygen ion conductor – $La_2Mo_{1.4}W_{0.6}O_9$ ceramic. XRD and TGA measurements demonstrate that this material is of β-$La_2Mo_2O_9$ structure from room temperature to 800 °C. Images from scanning electron microscopy reveal that the sample is composed of relatively oriented large blocks paralleling to the laser incident beam and its microstructure is totally different from those of conventionally sintered ceramic. Results of AC impedance spectroscopy indicate that the influence of grain boundaries is little in the crystal solidification direction and the samples exhibit high electrical conductivity. For example, the values are 2.2×10^{-3}, 0.017, 0.058 and 0.09 $\mathrm{S\,cm^{-1}}$ in dry air at 500, 600, 700 and 800 °C, respectively, which are about three to five times as high as those of samples prepared by solid state reaction method. It is suggested from the brick layer model that the main reason for the increase is the less grain boundary effect associated with the special microstructure of the samples.

14/01054 Experimental and numerical investigations of the optical and thermal aspects of a PCM-glazed unit

Gowreesunker, B. L. *et al. Energy and Buildings*, 2013, 61, 239–249.

This paper reports on the thermal and optical characterization of a phase change material (PCM), RT27, using the T-history method and spectrophotometry principles and the experimental and numerical performance evaluation of a PCM-glazed unit. Various relationships describing the variations in the extinction, scattering and absorption coefficients within the phase change region were developed, and were validated in a numerical computational fluid dynamics model. The results show that: (i) during rapid phase changes, the transmittance spectra from the PCM are unstable, while under stable conditions visible transmittance values of 90% and 40% are obtained for the liquid and phases, respectively; (ii) the radiation scattering effects are dominant in the solid phase of the PCM, while radiation absorption dominates in the liquid phase; (iii) the optical/radiation performance of PCM can be successfully modelled using the liquid fraction term as the main variable; (iv) the addition of PCM improves the thermal mass of the unit during phase change, but risks of overheating may be a significant factor after the PCM has melted; (v) although the day-lighting aspects of PCM-glazed units are favourable, the change in appearance as the PCM changes phase may be a limiting factor in PCM-glazed units.

14/01055 Fabrication of samarium doped ceria electrolyte on rough glass substrate with high electrical conductivity by electrostatic spray deposition for intermediate temperature solid oxide fuel cells

Chalermkiti, T. *et al. Energy Procedia*, 2013, 34, 471–478.

Samarium-doped ceria (SDC) thin films have been fabricated on unetched and etched glass substrates by an electrostatic spray deposition (ESD) technique for intermediate-temperature solid oxide fuel cells. The influence of substrate surface was studied to prepare a dense and crack-free SDC thin film with high electrical conductivity. With a heat treatment temperature of 400 °C, dense and crack-free SDC thin films were obtained on both unetched and etched glass substrates. The SDC films were nanocrystalline with cubic fluorite structure at the heat treatment temperature of 400 °C. The results revealed that the SDC film deposited on the etched glass substrate was smaller in thickness and higher in electrical conductivity than that on the unetched glass substrate. The maximum in electrical conductivity of the SDC film deposited on the etched substrate was approximately 1.34×10^{-1} S/cm at a low operating temperature of 600 °C.

14/01056 Fabrication of ultra-small texture arrays on multicrystalline silicon surface for solar cell application

Dou, B. *et al. Solar Energy*, 2013, 91, 145–151.

In this paper, ultra-small texture arrays have been synthesized via Ag and Ni catalysed etching on the multicrystalline silicon wafers. The wafers textured by Ni catalysed etching can obtain similar optical property to the ones textured by Ag catalysed etching. Then the corresponding solar cells of the two groups were manufactured and investigated. The performance of the solar cells textured via Ni catalysed etching is better, due to their lower recombination. In addition, as Ni is much cheaper than Ag, this Ni catalysed etching technique is promising to industrial fabrication.

14/01057 Lighting energy savings potential of split-pane electrochromic windows controlled for daylighting with visual comfort

Fernandes, L. L. *et al. Energy and Buildings*, 2013, 61, 8–20.

A simulation study was conducted to evaluate lighting energy savings of split-pane electrochromic (EC) windows controlled to satisfy key visual comfort parameters. Using Radiance lighting simulation software, interior illuminance and luminance levels were computed for a south-facing private office illuminated by a window split into two independently-controlled EC panes. The transmittance of these was optimized hourly for a work plane illuminance target while meeting visual comfort constraints, using a least-squares algorithm with linear inequality constraints. Blinds were successively deployed until visual comfort criteria were satisfied. The energy performance of electrochromics proved to be highly dependent on how blinds were controlled. With hourly blind position adjustments, electrochromics showed significantly higher (62% and 53%, respectively without and with overhang) lighting energy consumption than clear glass. With a control algorithm designed to better approximate realistic manual control by an occupant, electrochromics achieved significant savings (48% and 37%, respectively without and with overhang). In all cases, energy consumption decreased when the workplace illuminance target was increased. In addition, the fraction of time during which the occupant had an unobstructed view of the outside was significantly greater with electrochromics: 10 months out of the year versus a handful of days for the reference case.

14/01058 Methane hydrates formation and dissociation in nano silica suspension

Chari, V. D. *et al. Journal of Natural Gas Science and Engineering*, 2013, 11, 7–11.

Methane gas hydrate (MH) formation/dissociation were investigated in nano silica and water system in a non-stirred reactor. The MH yield was significantly improved in the presence of nano silica. The overall methane hydrate conversion ($\geq 80\%$) was achieved by optimizing the nano silica to water ratio. Two-stage dissociation was observed after a rapid depressurization. Methane gas intake of this system was steady for multiple freezing–thawing cycles signifying improved stability for methane gas storage.

14/01059 Next generation of ceramic hot gas filter with safety fuses integrated in venturi ejectors

Heidenreich, S. *et al. Fuel*, 2013, 108, 19–23.

The next generation of ceramic hot gas filter system of Pall Corporation with advanced venturi ejector blowback system, longer filter candles and safety fuses integrated in the venturi ejector is presented. The cleaning performance of the advanced venturi ejector blowback system has been investigated using filter candles of 1.5 m length with additionally installed safety fuses and with 2 m long filter candles with and without safety fuses. Measurements of the cleaning performance carried out for a group of 48 filter elements, which represents a cluster typically used in big commercial filter units, have shown that the efficiency reduction caused by using longer filter elements and additional safety fuses is compensated by the increased performance of the advanced modified blowback system. The option to install a safety filter element on each primary filter element increases the process safety of the filter system. Moreover, the use of longer filter elements offers lower system costs.

14/01060 Observation and possible mechanism of irradiation induced creep in ceramics

Katoh, Y. *et al. Journal of Nuclear Materials*, 2013, 434, (1–3), 141–151.

Stress relaxation of elastically strained silicon carbide samples during high flux neutron irradiation to about two displacements per atom at intermediate (390–540 °C) to high (790–1180 °C) temperatures is presented. The magnitude of stress relaxation normalized to the initial stress magnitude is independent of the initial stress magnitude, indicating a stress exponent of unity for irradiation creep in SiC. The creep strain increases with the increasing fluence while the strain rate significantly decreases. A linear relationship was found between the creep strain and the transient swelling that occurs due to irradiation defect accumulation. The apparent irradiation creep compliances for silicon carbide are substantially smaller than those associated with pure metals and alloys. Microstructural examination suggests that incoherent grain boundaries likely play a major role in determining the primary transient irradiation creep of these materials at high temperatures with a potential additional contribution from basal slip at very high temperatures.

14/01061 Optical characterisation and optimisation of a static window integrated concentrating photovoltaic system

Sellami, N. and Mallick, T. K. *Solar Energy*, 2013, 91, 273–282.

In this work, three different geometrical properties have been considered to develop a new solar concentrator design for window integrated concentrating photovoltaic (WICPV). They are (i) elliptical entry aperture; (ii) hyperbolic profile section and (iii) square exit aperture. Due to the increasing demands for stationary solar concentrators for building integrated photovoltaic (BIPV), this new design focuses on the use as a stationary solar concentrator. The complete optical analysis of the concentrator is carried out via three-dimensional ray trace technique. The analysis is based on all necessary design parameters, i.e. elliptical entry axis, concentrator height and the exit aperture geometry, in order to obtain the optimal overall optical performance of the new three-dimensional solar concentrator. Four different geometrical low concentration ratios were investigated: 4×, 6×, 8× and 10×. Results of the computer simulation show that the designed concentrator of 4× concentration ratio gives the higher optical efficiency of 68% compared to the other low concentration ratios. The 6×, however, gives a higher optical concentration ratio, despite having a lower optical efficiency (55%) than the 4×. A prototype of the designed concentrator was manufactured and tested under indoors conditions. The experimental results have shown an agreement by a difference of 5% with the simulation results. These results highlight how different factors need to be taken into consideration when carrying out optimization studies. Overall, the proposed concentrator looks promising with sound results to confirm its performance and validate it as a stationary solar concentrator and thereby promote its use in WICPV.

14/01062 Optimization of Al_2O_3–glass composite seals for planar intermediate-temperature solid oxide fuel cells

Wang, X. *et al. Journal of Power Sources*, 2013, 226, 127–133.

Al_2O_3–glass composite seals are fabricated by tape casting Al_2O_3 and HGS glass powder mixtures with glass contents ranging from 20 to 60 wt%. Their leaking performance is evaluated for various temperatures, gas pressures and compressive loads. The seal with optimized glass content is subjected to thermal cycling and single-cell tests to investigate the viability of the seal. The sealing performance of the seal is significantly improved by increasing the glass content in the composite seal; the seal containing 50 wt% glass (AG50) shows the best sealing performance among the studied compositions. Increasing the testing gas pressure or decreasing the testing temperature and compressive load increase the leak rate of the seal. After 25 thermal cycles between 750 and 200 °C, the leak rate of the AG50 seal is still below 0.021 sccm cm^{-1} under the conditions of 750 °C, a compressive load of 0.12 MPa and a testing gas pressure of 3.5–10.5 kPa. Using the AG50 seal, a high open circuit voltage of above 1.16 V after six thermal cycles is achieved for a $10 \times 10\,cm^2$ anode-supported single cell (active area of $9 \times 9\,cm^2$), which demonstrates the applicability of the AG50 seal in practical SOFC operations.

14/01063 Shortwave thermal performance for a glass window with a curved venetian blind

Chaiyapinunt, S. and Khamporn, N. *Solar Energy*, 2013, 91, 174–185.

This paper presents a study of thermal performance for a glass window with a curved venetian blind installed on the indoor side in terms of heat gain in the shortwave part of radiation. The curved venetian blind, whose optical properties are considered non-specular, is modelled as an effective layer. The mathematical model of the combined glass window and venetian blind is developed by combining the mathematical model of glass window and the mathematical model of a curved venetian blind using the matrix layer calculation method. The experiment is performed in a test room to measure the heat gain due to solar radiation passing through the glass window with a curved venetian blind installed in the shortwave part of radiation. The predicted results from the developed model are compared with the experimental results. The agreement between the predicted results and the experimental results is good. From the study it is found that installing a curved venetian blind to the glass window causes a significant reduction in heat gain compared to the plain glass window. The heat gain through the glass window with blind in the shortwave part of radiation (solar heat gain coefficient in the shortwave part of radiation (ShW SHGC)) is analysed. It is found that the ShW SHGC is mainly affected by the slat properties, slat angle and solar profile angle. The glass window using blind with a lower value of slat reflectance, will have a smaller value of ShW SHGC. The slat distance also affects the ShW SHGC. The glass window using blind with a lower value of slat distance has a lower value of ShW SHGC. The effect of the slat curvature on the ShW SHGC is small when compared to the effect of other parameters. The effects of the investigated parameters on the ShW SHGC for diffuse radiation are similar to the effects on the ShW SHGC for direct radiation. When installing blind to different kinds of glass window other than clear glass window, it is found that the thermal performance is similar to the case of clear glass window. The magnitude of the ShW SHGC for the glass window with blind is also dependent on the optical properties of the glass window used. The glass window with blind using a lower value of the glass transmittance has a lower value of the ShW SHGC. The absorptance of the glass window has direct effect on the solar heat gain coefficient in the longwave part of radiation (LoW SHGC).

14/01064 Statistical properties of fluctuation boiling centers on the wall of a silylated glass cell for n-pentane near the boundary of attainable superheat

Perminov, S. A. *et al. International Journal of Heat and Mass Transfer*, 2013, 57, (1), 429–431.

High-speed video has been first used to show visually the existence of reproducible fluctuation boiling centres on a solid wall of an experimental cell for liquids superheated to the attainable superheat boundary. The main statistical characteristics of fluctuation centres have been calculated with allowance for censoring. The non-stationarity of a fluctuation process leading to the appearance of a nucleus capable of spontaneous growth has been shown. The change in the density of distribution of probabilities of boiling-up on an ensemble of centres with an increase in their number has been demonstrated. With an increase in the number of centres the probability of observation of large lifetimes of a liquid in the state of superheating decreases rapidly.

14/01065 Triclinic $Na_{2-x}Fe_{1+x/2}P_2O_7$/C glass-ceramics with high current density performance for sodium ion battery

Honma, T. *et al. Journal of Power Sources*, 2013, 227, 31–34.

Triclinic $Na_{2-x}Fe_{1+x/2}P_2O_7$/C composite was prepared by glass-ceramics method. It was found that $Na_{2-x}Fe_{1+x/2}P_2O_7$/C composite can be used as cathode active materials for sodium ion battery with high current density rate performance over 10 C (2 mA cm^{-2}) condition and stable electrochemical cycle performance. A 2 μm glass precursor powder in composition of $Na_{2-x}Fe_{1+x/2}P_2O_7$ ($x = 0$–0.44) was crystallized in tubular furnace around 600 °C with carbon source to reduce iron valence state and to coat grain surface with carbon. By means of charge–discharge testing $Na_2FeP_2O_7$/C composite exhibits 86 mAh g^{-1}

($253\,\mathrm{Wh\,kg^{-1}}$) as reversible discharge energy density that is half amount of that for $LiFePO_4$, however in 10 C condition they kept $45\,\mathrm{mAh\,g^{-1}}$ ($110\,\mathrm{Wh\,kg^{-1}}$) even in 2 μm grain size.

14/01066 Understanding the effect of inert support on the reactivity stabilization for synthetic calcium based sorbents

Li, Z. *et al. Chemical Engineering Science*, 2013, 89, 235–243.

The decay of sorbent reactivity in multiple carbonation/calcination cycles is a critical problem for calcium looping. By introducing inert support materials into CaO particles, the cyclic reactivity of calcium based sorbent could be drastically improved. However, there is a lack of understanding of the interaction between the CaO grain and the support material; thus, much of studies of synthesizing calcium based sorbents are by trial-and-error. In order to understand the possible mechanism of synthetic calcium based sorbent, the widely accepted Zener pinning theory in the field of metallurgy was used here to describe the inhibition of CaO grain sintering due to the addition of inert support. A simple model of CaO grain growth for synthetic calcium-based sorbents was developed to analyse the effect of inert support on the stabilization of cyclic reactivity of CaO. The mechanism of sintering resistant in the synthetic calcium-based sorbents was the pinning force exerted by the dispersed support particles. The inhibition effect of inert support on CaO grain growth is related with the grain migration due to surface energy (γ), support size (r) and volume fraction (f), and the interaction (F_{interact}) between the support and CaO. The model was validated with the published data and can predict reasonably the experimental results, and the relative importance of some elementary steps was discussed. This study will provide a theoretical understanding for the further development and reactivity improvement of synthetic calcium-based sorbents.

14/01067 Windows in the buildings of tomorrow: energy losers or energy gainers?

Grynning, S. *et al. Energy and Buildings*, 2013, 61, 185–192.

One of the most effective actions for reduction of energy loss through the building envelope is to optimize the thermal performance, area and localization of the transparent components in the façade in order to obtain minimal heat losses and optimal solar gains. When considering the thermal performance of these transparent components, one should consider, not only heat loss (or gains) caused by thermal transmission, but also the beneficial effects of incident solar radiation and hence reduced demand for heating and artificial lighting. This study presents calculations for a range of windows as part of a building where the coupled effects of incident solar radiation and thermal transmission heat losses are accounted for in terms of a net energy balance for the various solutions. Effects of varying thermal transmittance values (U-values) are studied in connection with solar heat gain coefficients. Three different rating methods have been proposed and applied to assess the energy performance of several window configurations. It has been found that various rating methods give different energy saving potentials in terms of absolute figures. Furthermore, it has been found that windows, even with existing technology, might outperform an opaque wall in terms of heating and cooling demands.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

14/01068 A novel phosphonium-based deep eutectic catalyst for biodiesel production from industrial low grade crude palm oil

Hayyan, A. *et al. Chemical Engineering Science*, 2013, 92, 81–88.

This study explores the possibility of producing low grade crude palm oil (LGCPO)-based biodiesel using a two-stage process in which a phosphonium-based deep eutectic solvent (P-DES) and an alkali are used as catalysts. The pre-treatment of LGCPO was conducted using a P-DES composed of a hydrogen bond donor (i.e. *p*-toluenesulfonic acid monohydrate) and a salt (i.e. allyltriphenylphosphonium bromide) as a novel recyclable catalyst. The P-DES was used in different dosages in the presence of methanol to reduce the level of free fatty acids (FFA) to the acceptable limit for alkaline transesterification reaction. Batch pre-treatment of LGCPO was carried out to study the influence of P-DES dosage (from 0.25 to 3.5% wt/wt). The effects of other operating parameters such as molar ratio, reaction temperature and reaction time on FFA content reduction, yield of treated LGCPO and FFA to FAME conversion were studied. The P-DES showed high catalytic activity in the pre-treatment of LGCPO. The lab scale investigation proved the viability of esterification and transesterification of oil using P-DES and alkaline catalysts. The biodiesel produced from LGCPO meets the international standards (ASTM D6751 and EN 14214). Three to four times recycling runs of P-DES were achieved without losing its activity. This study introduces a new generation of catalysts for possible batch esterification reaction using P-DES followed by an alkaline transesterification reaction. This study will open a new field for utilizing this strong acid-based DES catalyst for many chemical reactions and industrial applications.

14/01069 Analysis of supply chain, scale factor, and optimum plant capacity for the production of ethanol from corn stover

Leboreiro, J. and Hilaly, A. K. *Biomass and Bioenergy*, 2013, 54, 158–169.

A detailed model is used to perform a thorough analysis on ethanol production from corn stover via the dilute acid process. The biomass supply chain cost model accounts for all steps needed to source corn stover including collection, transportation, and storage. The manufacturing cost model is based on work done at NREL; attainable conversions of key process parameters are used to calculate production cost. The choice of capital investment scaling function and scaling parameter has a significant impact on the optimum plant capacity. For the widely used exponential function, the scaling factors are functions of plant capacity. The pre-exponential factor decreases with increasing plant capacity while the exponential factor increases as the plant capacity increases. The use of scaling parameters calculated for small plant capacities leads to falsely large optimum plants; data from a wide range of plant capacities is required to produce accurate results. A mathematical expression to scale capital investment for fermentation-based biorefineries is proposed which accounts for the linear scaling behaviour of bio-reactors (such as saccharification vessels and fermentors) as well as the exponential nature of all other plant equipment. Ignoring the linear scaling behaviour of bio-reactors leads to artificially large optimum plant capacities. The minimum production cost is found to be in the range of \$789–830/$\mathrm{m^3}$ which is significantly higher than previously reported. Optimum plant capacities are in the range of 5750–9850 Mg/day. The optimum plant capacity and production cost are highly sensitive to farmer participation in biomass harvest for low participation rates.

14/01070 Are plant lipases a promising alternative to catalyze transesterification for biodiesel production?

Mounguengui, R. W. M. *et al. Progress in Energy and Combustion Science*, 2013, 39, (5), 441–456.

Interest in the production of biodiesel – a clean renewable fuel – is increasing worldwide. Industrial-scale processes currently being developed use homogenous and heterogeneous chemical catalysis processes that are highly efficient but require very pure reagents and complex product purification steps, or high temperature and pressure processing conditions. Enzymatic catalysis using plant lipases as biocatalysts is an alternative which, contrary to chemical catalysis processes, is simple to perform, at low investment cost, and therefore potentially easier to disseminate, especially in developing countries. Although microbial lipases have been extensively studied, little research has been focused on the use of plant lipases in biodiesel production. These latter lipases can, however, be readily extracted from the plant organs that contain them (seeds, bran or latex) and they are less expensive to use than microbial lipases. The aim of the present article was thus to review published research findings and outline the most advanced knowledge concerning alkyl ester production catalysed by plant lipases. This work focuses mainly on the conditions for using plant lipases in certain synthesis reactions (biomass selection, preparation and purification of lipase extracts) and current knowledge on reaction parameters that affect the catalytic activity. Moreover, biodiesel production using plant lipases and ethanol instead of methanol certainly seems to be in line with the development of innovative environment-friendly technologies.

14/01071 Arsenic volatilization in model anaerobic biogas digesters

Mestrot, A. *et al. Applied Geochemistry*, 2013, 33, 294–297.

Arsenic is a class 1 non-threshold carcinogen which is highly ubiquitous. Arsenic undergoes many different transformations (biotic or abiotic) between and within environmental compartments, leading to a number of different chemical species possessing different properties and toxicities. One specific transformation is As biotic volatilization which is coupled with As biomethylation and has been scarcely studied due to inherent sampling issues. Arsenic methylation/volatilization is also linked with methanogenesis and occurs in anaerobic environments. In China, rice straw and animal manure are very often used to produce biogas and both can contain high amounts of As, especially if the rice is grown in areas with heavy mining or smelting industries and if Roxarsone is fed to the animals. Roxarsone is an As-containing drug which is widely used in China to control coccidian intestinal parasites, to improve feed efficiency and to promote rapid growth. Previous work has shown that this compound degrades to inorganic As under anaerobic conditions. In this study the focus is on biotic transformations of As in small microcosms designed as biogas digester models (BDMs) using recently validated As traps, thus, enabling direct quantification and identification of volatile As species. It is shown that although there was a loss of soluble As in the BDMs, their conditions favoured biomethylation. All reactors produced volatile As, especially the monomethylarsonic acid spiked ones with 413 ± 148 ng As (mean ± SD, $n = 3$) which suggest that the first methylation step, from inorganic As, is a limiting factor. The most abundant species was trimethylarsine, but the toxic arsine was present in the headspace of most of the BDMs. The results suggest that volatile As species should be monitored in biogas digesters in order to assess risks to humans working in biogas plants and those utilizing the biogas.

14/01072 Catalytic transesterification of high viscosity crude microalgae lipid to biodiesel: effect of co-solvent

Lam, M. K. and Lee, K. T. *Fuel Processing Technology*, 2013, 110, 242–248.

Cultivating microalgae for biodiesel production is a new and emerging research field that has the potential to revolutionize the renewable energy industries. However, up to now, comprehensive study on the conversion efficiency of microalgae lipid to biodiesel is still inadequate. In the present study, reaction optimization studies were carried out to convert high viscosity microalgae lipid (extracted from *Chlorella vulgaris*) to biodiesel by using sulfuric acid (H_2SO_4) as catalyst. In order to attain 95% fatty acid methyl ester (FAME) content, the optimized reaction conditions were as follows: a methanol to lipid molar ratio of 180, a catalyst concentration of 35 wt%, a temperature of 60 °C and a reaction time of 6 h. Due to the high requirement of methanol and catalyst concentration, attempt was made to improve the reaction conditions by introducing a co-solvent into the reaction mixture. It was found that tetrahydrofuran (THF) could significantly enhance the reaction rate by homogenizing the reaction mixture. The optimum reaction conditions with a co-solvent were found to be less extreme: a methanol to THF to lipid molar ratio of 60 : 15 : 1, a catalyst concentration of 21 wt%, a temperature of 60 °C and a reaction time of 3 h.

14/01073 Economic feasibility of biodiesel production from Macauba in Brazil

de Carvalho Lopes, D. *et al. Energy Economics*, 2013, 40, 819–824.

In this work the economic feasibility of biodiesel production in Brazil by using the Macauba oil as raw matter is studied. The software SIMB-E, in which a cash flow model applied to biodiesel production is implemented, was used during simulations. Economic indexes related to biodiesel production features, as well as the competitiveness between selling prices of biodiesel and petrodiesel were considered. It was found that all of the eight simulated scenarios were potentially profitable, but only two of them presented competitive biodiesel selling prices, being considered as worthwhile projects. These were seed-oil plants with alkaline transesterification. Results also indicated that the success of biodiesel production still requires additional revenues beyond that derived from biodiesel itself, including income from the feedstock coproducts and glycerol. Macauba showed to be a potential crop to be used in biodiesel production. However, the domestication and improvement on processing of this species are indispensable to ensure its availability of long-term use.

14/01074 Economy-wide impacts of biofuels in Argentina

Timilsina, G. R. *et al. Energy Policy*, 2013, 55, 636–647.

Argentina is one of the world's largest biodiesel producers and the largest exporter, using soybeans as feedstock. Using a computable general equilibrium model that explicitly represents the biofuel industry, this study carries out several simulations on two sets of issues: (i) international markets for biofuel and feedstock, such as an increase in prices of soybean, soybean oil, and biodiesel, and (ii) domestic policies related to biofuels, such as an introduction of biofuel mandates. Both sets of issues can have important consequences to the Argentinean economy. The simulations indicate that increases in international prices of biofuels and feedstocks would increase Argentina's gross domestic product and social welfare. Increases in international prices of ethanol and corn also can benefit Argentina, but to a lesser extent. The domestic mandates for biofuels, however, would cause small losses in economic output and social welfare because they divert part of biodiesel and feedstock from exports to lower-return domestic consumption. An increase in the export tax on either feedstock or biodiesel also would lead to a reduction in gross domestic product and social welfare, although government revenue would rise.

14/01075 Effect of sodium hydroxide pretreatment on physical, chemical characteristics and methane production of five varieties of sorghum

Sambusiti, C. *et al. Energy*, 2013, 55, 449–456.

Sorghum bicolor (L.) Moench, represents an interesting substrate for methane production. The aim of this study was to evaluate the effect of alkaline pretreatment on chemical composition, physical structure and methane production of five varieties of sorghum (S1, S2, S3, S4 and S5). The pretreatment was conducted in closed bottles, at 55 °C for 12 h. Samples were soaked in a NaOH solution at 4 and 10 gNaOH/100 gTS, with a solid concentration of 35 gTS/L. Sodium hydroxide pretreatment led to a reduction of lignin (50–70%), hemicelluloses (18–35%), cellulose (16–45%) and galacturonic acids (up to 100%), for all varieties of sorghum, as also confirmed by Fourier transform infrared spectroscopy analyses. The reduction of lignin content and thereafter the solubilization of cellulose and hemicelluloses, previously observed, can accelerate the disintegration and the hydrolysis steps during anaerobic digestion. Indeed, an increase in the first order kinetic constant was observed by increasing the alkaline dosage (by 40%, 61%, 64%, 54% and 40% for sorghum S1, S2, S3, S4 and S5, respectively). Nevertheless, the sodium hydroxide pretreatment had no positive effect in enhancing the methane yields (270 ± 13, 335 ± 11, 294 ± 1, 327 ± 9 and 303 ± 24 mL CH_4/gVS for S1, S2, S3, S4 and S5, respectively).

14/01076 Effects of temperature on the yields and properties of bio-oil from the fast pyrolysis of mallee bark

Mourant, D. *et al. Fuel*, 2013, 108, 400–408.

Bark constitutes an important part of any woody biomass to be used for the production of second generation biofuels and chemicals. Pyrolysis followed by biorefinery is a promising technology for the efficient utilization of all components from a woody crop. While significant efforts have been devoted to the investigation of the pyrolysis characteristics of wood, relatively less is known about the pyrolysis behaviour of bark. This study aims to clarify the effects of temperature on the yields and composition of bio-oil from the pyrolysis of eucalypts bark. The bark of mallee, a type of eucalypt grown for soil amendment in Western Australia, was pyrolysed between 300 and 580 °C at fast heating rates in a fluidized-bed pyrolysis unit. The bio-oil liquid products separate into two phases. The bio-oil liquid products were analysed by GC–MS, Karl-Fischer titration, UV-fluorescence spectroscopy, ICP-OES and thermogravimetric analysis. These results are compared, when appropriate, to those obtained from the wood fraction.

14/01077 Effects of ultrasonic and thermo-chemical pre-treatments on methane production from fat, oil and grease (FOG) and synthetic kitchen waste (KW) in anaerobic co-digestion

Li, C. *et al. Bioresource Technology*, 2013, 130, 187–197.

The effects of ultrasonic and thermo-chemical pre-treatments on the methane production potential of anaerobic co-digestion with synthetic kitchen waste (KW) or fat, oil and grease (FOG) were investigated. Non-linear regressions were fitted to accurately assess and compare the methane production from co-digestion under the various pre-treatment conditions and to achieve representative simulations and predictions. Ultrasonic pre-treatment was not found to improve methane production effectively from either FOG co-digestion or KW co-digestions. Thermo-chemical pre-treatment could increase methane production yields from both FOG and KW co-digestions. COD solubilization was found to effectively represent the effects of pre-treatment. A comprehensive evaluation indicated that the thermo-chemical pre-treatments of pH = 10, 55 °C and pH = 8, 55 °C provided the best conditions to increase methane production from FOG and KW co-digestions, respectively. The most effective enhancement of biogas production (288 ± 0.85 mL CH_4/g TVS) was achieved from thermo-chemically pre-treated FOG co-digestion, which was 9.9 ± 1.5% higher than FOG co-digestion without thermo-chemical pre-treatment.

14/01078 Efficient procedure for biodiesel synthesis from waste oils using novel solid acidic ionic liquid polymer as catalysts

Liang, X. *et al. Fuel Processing Technology*, 2013, 110, 109–113.

The novel solid acidic ionic liquid polymer has been synthesized through the copolymerization of acidic ionic liquid oligomers and divinylbenzene. The catalytic activities were investigated through the biodiesel synthesis from waste oils. The results showed that the polymeric ionic liquid (PIL) was very efficient for both the transesterification of triglycerides and esterification of free fatty acids with the yield of 99.0%. The procedure was quite simple with just one-step to complete both the reactions under mild reaction conditions. The high hydrophobic Brunauer–Emmett–Teller surface, high catalytic activities and high stability were the key properties of the PIL.

14/01079 Ethanol production by simultaneous saccharification and fermentation in rotary drum reactor using thermotolerant *Kluveromyces marxianus*

Lin, Y.-S. *et al. Applied Energy*, 2013, 105, 389–394.

The production of ethanol from sugarcane bagasse by simultaneous saccharification and fermentation (SSF) using thermotolerant *Kluveromyces marxianus* var. *marxianus* and commercial cellulase of Accellerase 1000 was investigated. Sugarcane bagasse pretreated with NaOH at the room temperature for 24 h resulted in an increase in cellulose content to 55.2% (w/w). With 10% of water-insoluble-solids (WIS) at pH 5.0 supplemented with 0.2 ml cellulase/g-WIS and 1 g/L of thermotolerant yeast, the SSF of pretreated sugarcane bagasse conducted in flasks led to a respective theoretical ethanol yield of 85.1%, 92.2% and 76.2% under 37, 42 and 45 °C. As the rotary drum reactor was scaled up to 100 L and loaded with 10 kg alkali-pretreated sugarcane bagasse, the SSF at 42 °C for 72 h along with same doses of WIS, cellulase and yeast resulted in a final ethanol concentration and the theoretical ethanol yield of 24.6 g/L and 79%, respectively. These observations indicated that the performance and the chosen SSF operating conditions for the scale-up drum reactor was as effective as those attained from flask runs. As demonstrated, the use of rotary drum reactor for cellulosic ethanol production under SSF operating conditions is simple to scale up and shows commercial potential.

14/01080 Experimental investigation on the combustion and heat transfer characteristics of wide size biomass co-firing in 0.2 MW circulating fluidized bed

Sun, P. *et al. Applied Thermal Engineering*, 2013, 52, (2), 284–292.

In order to reduce emissions and enhance combustion efficiency and bed-to-wall heat transfer in circulating fluidized bed (CFB), wide size crushed biomass pellets were adopted for co-firing. The influences of biomass share on bed pressure, temperature profiles, fly ash loss, heat transfer, and gaseous pollutant emissions were studied by experiments performed in a 0.2 MW pilot scale CFB. Results show that with higher biomass share, more uniform axis temperature profiles, lower fly ash loss, less gaseous emission and higher bed-to-wall heat transfer can be achieved, but the effect of biomass share on bed pressure and porosity is minor. As biomass share increases, the reducing atmosphere formed at the upper part of the dense zone is enhanced, and the temperature at the lower part is decreased. This inhibits the formation of NO, N_2O and SO_2 in the dense zone, while promotes their reduction, so lower gaseous emissions are obtained. Biomass char with small diameter that generated in the dense zone can be consumed soon after the introduction of secondary air, which achieves lower fly ash loss. The fine particles yielded from biomass combustion reduce the thickness of the heat-conduction gas layer between clusters and water wall, and the heat transfer coefficient can be improved by 10%.

14/01081 Fast pyrolysis of Amazon *tucumã* (*Astrocaryum aculeatum*) seeds in a bubbling fluidized bed reactor

Lira, C. S. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 23–31.

Biofuels are often presented as a contribution toward the solution of the problems related to the world's strong dependency on fossil fuels, such as greenhouse gas effects and urban pollution, in addition to being a way to support rural development. Biomass is the most important renewable energy source and the state of Amazon in Brazil, which is completely covered by the Amazon rainforest, has great potential as a source of biomass. The aim of this research was to study the conversion process of the seed residue of Amazon *tucumã* (*Astrocaryum aculeatum*) into bio-oil by fast pyrolysis. The seed residue was ground and samples with a diameter smaller than 2 mm were pyrolysed in a bubbling fluidized bed of inert silica sand. The residence time of gases was maintained at 1.4 s with the reactor temperatures ranging from 400 to 600 °C. All liquid and solid products generated during the process were weighed, analysed, and characterized (HHV, GC–MS, ultimate analysis and ash mineral analysis). The resulting bio-oil was a homogeneous fuel, with a maximum liquid yield of 60 wt% at 500 °C, with a water-free high heating value (HHV) of 20.2 MJ/kg. The highest water-free HHV (30.5 MJ/kg) was found at 550 °C, for which the liquid yield was around 55 wt%. The results demonstrated that there is a great potential for using the bio-oil from Amazon *tucumã* for bio-fuel production in addition to the production of some high-value compounds, such as levoglucosan and guaiacol.

14/01082 Feasibility study of a spouted bed gasification plant

Bernocco, D. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 843–855.

In this study, the authors have studied the feasibility of building a biomass gasification plant with an innovative spouted bed reactor for distributed energy production. The process was simulated using a thermodynamic approach (concentrated parameter model) using LIBPF, a C++ process modelling library. A nominal size of about 100 kW total thermal power was chosen. Fifteen chemical species were taken into account (dry and ash-free (daf) biomass, C, CH_4, CO, CO_2, H_2, H_2O, N_2, NH_3, O_2, methanol, ethylene, phenol, naphthalene and ash). After preliminary simulation trials and unit operation sizing, a proper plant configuration was developed. The air equivalent ratio (ER), syngas condensate recycling and biomass moisture fraction were studied in compliance with the constraint of the gas flow required for a stable spouting regime (120 m^3/h) and optimal gasification temperature (930 °C). A working condition map was obtained in terms of air ER and syngas condensate recycling for different biomass moisture fractions and the main plant performance parameters were studied. The net electrical yield was found to vary from the ideal maximum of 25% to a minimum of about 17% and the heat cogeneration yield was found to vary in the range 45–48% for all the process conditions studied.

14/01083 Fluid-dynamic characterization of real-scale raceway reactors for microalgae production

Mendoza, J. L. *et al. Biomass and Bioenergy*, 2013, 54, 267–275.

The fluid dynamic characterization of a 100 m length × 1 m wide channel raceway photobioreactor was carried out. The effects of water depth, liquid velocity and the presence, or absence, of sump baffles to improve the CO_2 supply transfer were considered in relation to on the power consumption, residence time and mixing in the reactor was studied. When operated at a depth of 20 cm, the power consumption was between 1.5 and 8.4 $W\,m^{-3}$ depending on the forward velocity, with higher values occurring when the baffle was in place. Residence times and the degree of mixing at each section of the raceway (paddlewheel, bends, channels and sump) were measured experimentally. Mixing occurred mainly in the sump, paddlewheel and bends, with a maximum dispersion coefficient of 0.07 $m^2\,s^{-1}$. These sections, however, only contributed a small fraction to the total volume of the raceway. Bodenstein numbers from 200 to 540 for the channel sections indicated plug-flow characteristics. Mixing times ranged from 1.4 to 6 h, with the presence of the baffle greatly increasing these times despite higher specific power consumption. A total of 15–20 circuits of the raceway were needed to achieve complete mixing without the baffle, compared to 30–40 cycles with the baffle. Vertical mixing was very poor whereas axial mixing was similar to that achieved in closed photobioreactors. The methodologies applied were shown to be useful in determining the fluid dynamics of a raceway photobioreactor. Equations useful in simulating the power consumption as a function of the design and operation parameters have been validated.

14/01084 Fuel properties, engine performance and environmental benefits of biodiesel produced by a green process

Chattopadhyay, S. and Sen, R. *Applied Energy*, 2013, 105, 319–326.

Biodiesel, produced by enzymatic transesterification of cottonseed oil with methanol in a green, zero waste discharge process, was purified to meet the international specifications. Glycerol was recovered by gravity separation and unutilized methanol was recycled after distillation. The methyl ester content of the purified product was found to be almost 90%. The fuel properties of the product and its blends with petroleum diesel were in well accordance with the international standards. The performance characteristics of the diesel engine with the blends (B10 and B20) were comparable to that of diesel in terms of brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT). The emission characteristics of the engine with the blends were such that significant environmental benefits could be accrued, as the average emissions of CO, CO_2, smoke and unburned hydrocarbons (HCs) got considerably reduced by 33.3%, 8.4%, 43.4% and 29.4%, respectively. However, in case biodiesel, relatively higher levels of NO_X emission can be attributed to the inherent oxygen of biodiesel. Thus, the B10 and B20 products based on biodiesel from the green process showed comparable engine performance with better greenhouse gas emission characteristics and hence, deserve the status of an efficient environment friendly bio-additive for diesel engines.

14/01085 Fuzzy decision support methodology for sustainable energy crop selection

Balezentiene, L. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 83–93.

Both strategic and environmental factors make biomass an important energy source and element of sustainable energy policy. The establishment of a reasonable energy crop-mix, indeed, involves various uncertain data. This paper, therefore, offers a multi-criteria decision-making framework for prioritization of energy crops based on fuzzy MULTIMOORA method which enables to tackle imprecise information. Given the appropriate energy crop-mix should exhibit both climatic suitability and low environmental pressure, the authors have defined the indicator set covering respective linguistic and numeric indicators. Accordingly, the set of alternatives were constructed from energy crops suitable for the Lithuanian climate. The fuzzy MULTIMOORA method was employed for data fusion and prioritization. As a result, several novel crops for a Boreal-Nemoral region, namely Lithuania, were identified by considering multiple environmentally compatible indices by the virtue of the multi-criteria ranking. Besides giant reed (*Arundo donax* L., mixed *Festuca arundinacea* + *Melilotus alba*, cup plant (*Siphium perfoliatum* L.), virginia mallow (*Sida hermaphrodita* L. Rusby), and giant silver grass (*Miscanthus gigan-*

theus), they include maize biomass, reed canary grass (*Phalaris arundicancea* L.), mix *Galega orientalis* Lam. + *Phalaris arundinacea* L., permanent grasses (*Festuca arundinacea*; *Bromus tectorum*; *Phalaris arundinacea* L.; *Dactylis glomerata* L.). Lignified sustainable energy crops, namely black poplar (*Populus nigra* L.) and willow (*Salix viminalis* L.), attracted particular interest as vegetation filters for sewage. This research is likely to be further incentivized by foreseeing prospective biomass crops and their competition with food and feed production. Indeed, considerable research on land re-allocation and fieldwork are still required in Lithuania to obtain more certain estimates for multi-criteria decision making.

14/01086 GIS-based biomass resource utilization for rice straw cofiring in the Taiwanese power market

Hu, M.-C. *et al. Energy*, 2013, 55, 354–360.

This research evaluated the potential development of biomass cofiring systems in the Taiwanese electric power market. A linear complementarity model was established to simulate the electricity market. Rice straw, an agricultural waste residue from rice cultivation, was considered as a combustion feedstock. A supply system for the biomass feedstock was built for the rice straw cofiring system and a geographic information system (GIS)-based spatial analysis of the rice straw supply system was carried out. Rice straw cofiring systems in the main coal-fired power plants are simulated in this research. The spatial distribution of paddy rice straw is considered for rice straw collection in Taiwanese cofiring systems. GIS analysis was implemented to identify rice straw farms near power plants as the first priority sources to reduce the transportation cost. As the straw-power percentage increased from 0.5% to 3%, total straw demand increased from 315,891 to 1,895,345 Mg. Meanwhile, the total area of the source farms ranged from 52,648 to 315,891 ha; total CO_2 emissions reductions increased from 318,987 to 1,913,920 Mg. The limitation of the market equilibrium model includes rice straw supply and power generation capacity constraints. The supply of rice straw is restricted because of the limited rice farm. The GIS-based spatial analysis of resources (paddy rice straw) supply is considered in the model; then the shortest route is determined to deliver biomass feedstock from fields to cofiring power plants in Taiwan. Furthermore, the installed generation capacity constraint for power plants is considered. The contribution of this paper includes analysis of the rice straw cofiring penetration in the power market, linear complementarity models to simulate the power market equilibrium with cofiring systems, and GIS-based analysis to examine the geospatial relationships between paddy rice farms and power plants to assess potential biomass for straw-power generation. The results show the spatial maps and equilibrium of rice straw cofiring in Taiwanese power market.

14/01087 Improving the low temperature flow properties of palm oil biodiesel: addition of cold flow improver

Lv, P. *et al. Fuel Processing Technology*, 2013, 110, 61–64.

Palm methyl ester (PME) was prepared using an alkali-catalysed transesterification reaction, and its cold flow properties (CFP) were studied. Commercial DEP (trade name) and polyglycerol ester (PGE), and self-made 'PA' (given name by the laboratory researchers), were used as cold flow improvers (CFIs) to improve the CFP of the biodiesel, and the effects of these CFIs on the CFP of PME were investigated. The results showed that the peak crystallization temperature of PME was very close to the cold filter plug point (CFPP). There was no unique linear relationship between the CFPP and the content of saturated fatty acid methyl esters. When used individually as CFIs, DEP, PGE and PA exerted only moderate pour point depression effects on the biodiesel, and effects to decrease the CFPP of PME were only observed when the CFI concentration was 1% or higher. Compared with single-compound CFIs and CFIs formulated from two components, at a specified complex formulation ratio, CFIs formulated from three components exhibited the best performance. When the ratio of DEP : PGE : PA was 3 : 1 : 1 or 2 : 2 : 1, the CFPP of PME was decreased by 7 °C.

14/01088 Is there a role for biofuels in promoting energy self sufficiency and security? A CGE analysis of biofuel policy in Thailand

Wianwiwat, S. and Asafu-Adjaye, J. *Energy Policy*, 2013, 55, 543–555.

Given the rising price of crude oil, some developing countries including Thailand are looking towards developing their domestic renewable energy resources, in particular biofuels. However, there are concerns about the possible adverse effects such a policy strategy would have on key variables such as sectoral output, land allocation and the effects of prices, particularly food prices. This study develops a computable general equilibrium (CGE) model of the Thailand economy that features enhancements of the energy sector and uses it to analyse the government's recent renewable energy development plan. This plan aims to increase domestic energy use from renewable sources to replace fossil fuel imports. The study simulated specific policies contained in the plan. Among other things, the authors found that promoting biofuel use causes a rapid increase in the price of biofuel and biofuel feedstock in the short-run, whereas these prices only increase slightly in the long-run due to more elastic supplies. The prices of food and other products marginally increase, implying that food security is not undermined by the policy. On the basis of the findings, the study recommends a review of some of the targets because they were found to be rather high, and a phasing in of others.

14/01089 Life cycle optimization for sustainable design and operations of hydrocarbon biorefinery via fast pyrolysis, hydrotreating and hydrocracking

Gebreslassie, B. H. *et al. Computers & Chemical Engineering*, 2013, 50, 71–91.

This paper addresses the optimal design and operation of hydrocarbon biorefinery via fast pyrolysis, hydrotreating and hydrocracking of hybrid poplar feedstock under economic and environmental criteria. The hydrocarbon biorefinery encompasses fast pyrolysis for crude bio-oil production, upgrading of the bio-oil through hydrotreating, separation and hydrocracking of long chained hydrocarbons into gasoline and diesel range products, and steam reforming for hydrogen production. The authors propose a bi-criteria non-linear programming (NLP) model that seeks to maximize the economic performance measured by the net present value (NPV) and to minimize the environmental impacts. The environmental objective is measured with the global warming potential (GWP) metric according to the life cycle assessment procedures, which covers gate-to-gate environmental impacts of the hydrocarbon biorefinery. The multiobjective NLP model simultaneously determines the production capacity, size of each process units, operational conditions, the flow rates of species and streams at each stage of the process, hydrocarbon biofuel yields, and consumption rate of feedstock, steam, electricity, and natural gas. The bi-criteria NLP model is solved with the ϵ-constraint method, and the resulting Pareto-optimal curve reveals the trade-off between the economic and environmental dimensions of the sustainable hydrocarbon biorefinery. The optimization results reveal that the unit production cost of the hydrocarbon biofuels is \$2.31 per gallon of gasoline equivalent (GGE) for the maximum NPV solution and \$3.67/GGE for the minimum GWP design. The corresponding greenhouse emission is 8.07 $kgCO_{2\text{-eq}}$/GGE.

14/01090 Metrics for evaluating the forest biorefinery supply chain performance

Mansoornejad, B. *et al. Computers & Chemical Engineering*, 2013, 54, 125–139.

For sustainable decision-making regarding biorefinery strategies, different criteria, i.e. economic, environmental, social, should be considered. However, the economic criteria typically do not consider market volatility, whereas today's market involves price and demand volatilities. Biorefinery strategies must be flexible to be robust to market volatility. Therefore, relevant metrics must be developed to quantify the system's performance against volatility. This paper presents metrics of flexibility and robustness which analyse the performance of the supply chain in a dynamic environment, providing additional information along with economic metrics. In this paper, the link between the two metrics, and how profitability and robustness change with flexibility are discussed. The results reveal that, although profitability does not always increase with more flexibility and there is an optimum level of flexibility, the system's robustness is improved by increasing flexibility. Moreover, a 'conditional value-at-risk' parameter is introduced to show what patterns of sale lead to highest profit and robustnestness.

14/01091 Modeling, simulation and control of an internally heat integrated pressure swing distillation process for bioethanol separation

Shirsat, S. P. *Computers & Chemical Engineering*, 2013, 53, 201–202.

Ethanol produced from biomass is one of the most promising renewable fuels. However, most of the proposed separation methods use volatile organic compounds as solvents. Because such solvents are environmentally hazardous, new, efficient and sustainable ways of alcohol purification process ought to be developed. Ideally, no solvent should be required for the high purity purification of alcohol aqueous solutions. Therefore, in this work the modelling, simulation and control of an internally heat integrated pressure-swing distillation process to separate the ethanol/water azeotropic binary system into a high purity ethanol stream are addressed. By means of the proposed separation process, high-purity ethanol, suitable for use in the transportation sector, is obtained. Despite the high interaction between the column sections, the results show that the proposed separation process can be operated smoothly with an array of PI controllers. Moreover, the purity of ethanol is maintained with the control structure proposed in the face of upsets.

14/01092 Nickel-catalysed pyrolysis/gasification of biomass components

Wu, C. *et al. Journal of Analytical and Applied Pyrolysis*, 2013, 99, 143–148.

Hydrogen and syngas production have been investigated from the pyrolysis/gasification of biomass components (cellulose, xylan and lignin) in the presence of Ni-based catalysts by using a two-stage fixed-bed reaction system. Biomass samples were pyrolysed at the first stage and the derived products were gasified at the second stage. The Ni–Mg–Al and Ni–Ca–Al catalysts, prepared by co-precipitation, were applied in the gasification process. The lignin sample pyrolysed with more difficulty (56.0 wt% of residue fraction) compared with cellulose and xylan at 500 °C, and therefore resulted in the lowest gas yield (42.7 wt%) for the pyrolysis/gasification of lignin. However, the highest H_2 concentration from the three types of feedstock (55.1 vol.%) was collected for the lignin sample in the presence of steam and catalyst. Carbon deposition was very low as indicated from the TPO and SEM analyses of the reacted Ni–Mg–Al catalyst. The investigation of reaction conditions showed that water injection rate (0.02 and $0.05\,\mathrm{g\,min^{-1}}$) had little influence on the gas production from the pyrolysis/gasification of lignin in the presence of the Ni–Ca–Al catalyst; however, the increase of gasification temperature from 700 to 900 °C resulted in a higher gas and hydrogen production due to the promotion of secondary reactions during the gasification process. Furthermore, coking was highest for the reacted Ni–Ca–Al catalyst at the gasification temperature of 800 °C (7.27 wt%), when the temperature was increased from 700 to 900 °C. This work shows that the components of biomass have a significant influence on the catalytic gasification process related to hydrogen and syngas production.

14/01093 Production of bio-ethanol from three varieties of dates

Louhichi, B. *et al. Renewable Energy*, 2013, 51, 170–174.

In this work, production of bio-ethanol from three varieties of dates (Kunta, Eguoua and Bouhatem) produced in the region of Gabès in Tunisa was studied. A comparison between soxhlet and solvent extraction of a juice obtained from the dates was made. The alcoholic fermentation of this juice by *Saccharomyces cerevisiae* was investigated under sugar concentration near $200\,\mathrm{g\,L^{-1}}$ at 30 °C and natural pH. The obtained results showed that all the tested varieties allowed producing ethanol with a concentration around 25% (V/V). Moreover the yeast used in the fermentation process is capable of producing alcohol even at a pH of 3.8.

14/01094 Scenario analysis of large scale algae production in tubular photobioreactors

Slegers, P. M. *et al. Applied Energy*, 2013, 105, 395–406.

Microalgae productivity in tubular photobioreactors depends on algae species, location, tube diameter, biomass concentration, distance between tubes and for vertically stacked systems, the number of horizontal tubes per stack. A simulation model for horizontal and vertically stacked horizontal tubular reactors was made to quantify the effect of these decision variables on production yield. The model uses reactor dimensions, dynamic sunlight patterns over the day and year, and growth characteristics of algae species as inputs. Scenario studies were done to study the effect of decision variables on reactor performance in The Netherlands, France and Algeria. Results indicate that the areal biomass productivity in vertically stacked photobioreactors is 25–70% higher than in plain horizontal systems. Reactor design is location specific because light conditions differ. In The Netherlands, the best horizontal distance between tubes is 0.05 m for horizontal and 0.25 m for vertical systems. For France and Algeria, the best horizontal distance between vertical systems is 0.20 and 0.15 m, respectively. System performance can be improved further by using light reflection materials on the ground surface. Improving the transparency properties of tube material does not significantly affect areal productivity.

14/01095 Studies on cracking of Jatropha oil

Biswas, S. and Sharma, D. K. *Journal of Analytical and Applied Pyrolysis*, 2013, 99, 122–129.

Pyrolysis/cracking of non-edible plant seed oil Jatropha oil (JO) and the utilization of cracked liquid product as a transportation fuel have gained importance due to the growing demand of renewable fuel oil source and depleting fossil fuel reserves. Thus, an attempt has been made to study the non-isothermal kinetics of JO cracking/pyrolysis using thermogravimetric analysis. The experiments were carried out at different heating rates of 5, 10, 15 and $20\,\mathrm{K\,min^{-1}}$ under nitrogen atmosphere from ambient temperature to 1073 K. The degradation of JO was found to occur in three steps. The main devolatilization of JO occurs in the temperature region 623–753 K and the degradation is essentially complete in this zone. Kinetic studies using isoconversional Friedman's plots obtained for JO degradation show the presence of two regions of JO degradation. The average activation energy calculated for the first region was 114.49 kJ/mol and for the second region was 221.88 kJ/mol. For better understanding of JO cracking, the cracking of JO was also carried out in a batch reactor and the liquid, gaseous product and char obtained were analysed. Both the methods revealed that there is a complete conversion of JO. The liquid product obtained from JO cracking was found to contain alkanes, alkenes, cycloalkanes and carboxylic acids. The gaseous product obtained consisted of methane, pentane, iso-butane and certain uncondensed components (greater than C5 carbons). The char obtained had high carbon content and showed the presence of K, Mg and Fe.

14/01096 Sugar beet for bioethanol production: an approach based on environmental agricultural outputs

Salazar-Ordóñez, M. *et al. Energy Policy*, 2013, 55, 662–668.

The European Union (EU) imports both bioethanol and the raw material needed to produce it. Thirty per cent of bioethanol is produced from sugar beets in the EU. However, sugar beet cultivated area and yields have fallen due to the 2006 sugar regime reform. Given the potential uncertainty about the future for sugar beet farmers, biofuels may represent an alternative market. This paper analyses potential contribution to the efficiency, in terms of environmental output, of the sugar beet crop both when production is oriented toward bioethanol and regarding the use of input. An empirical application is performed in Spain by data envelopment analysis (DEA). The results show that 4% of farms have full technical efficiency, while the rest have an average efficiency of 55.9%. The figures show that inputs can be reduced over 40%, and also show the low average level of input-use efficiency. In addition, it cannot be said that there is a relationship between efficiency and farm scale. The consideration of aspects such as the environmental advantages of using sugar beet production for bioethanol can open new lines of action to support this crop in the EU. In addition, boosting sugar beet production may reduce potential dependency on importation.

14/01097 Sugarcane straw availability, quality, recovery and energy use: a literature review

Leal, M. R. L. V. *et al. Biomass and Bioenergy*, 2013, 53, 11–19.

Sugarcane straw represents, under Brazilian conditions, approximately one third of the total primary energy of sugarcane in the field. Today, its use for energy is incipient and it is mostly wasted by either burning in the pre-harvest or left on the ground to decay. Besides its potential use as feedstock for energy production, there are several possible agronomic benefits of the straw blanket left on the ground such as soil protection against erosion, increase of soil organic carbon content, inhibition of weed growth, nutrient recycling and reduction of soil water losses, to name a few. The balance of the impacts and the economic and energetic value of the straw indicate that the amount of the straw left on the ground that could be considered optimal is dependent on the local conditions, agricultural practices, characteristics of the straw and intended final use. This work sheds some light into this subject to help the understanding of the importance of the various impacts of the straw blanket on the ground, the availability and quality of the straw, the economics of straw recovery and use and the main criteria for determining the amount of straw that can be recovered for bioenergy or biofuels production.

14/01098 Time–frequency dynamics of biofuel–fuel–food system

Vacha, L. *et al. Energy Economics*, 2013, 40, 233–241.

For the first time, this study applies the wavelet coherence methodology on biofuels (ethanol and biodiesel) and a wide range of related commodities (gasoline, diesel, crude oil, corn, wheat, soybeans, sugarcane and rapeseed oil). This way, the authors are able to investigate dynamics of correlations in time and across scales (frequencies) with a model-free approach. The authors show that correlations indeed vary in time and across frequencies. They find two highly correlated pairs which are strongly connected at low frequencies – ethanol with corn and biodiesel with German diesel – during almost the whole analysed period (2003–2011). Structure of correlations remarkably changes during the food crisis – higher frequencies become important for both mentioned pairs. This implies that during stable periods, ethanol is correlated with corn and biodiesel is correlated with German diesel mainly at low frequencies so that they follow a common long-term trend. However, in the crisis periods, ethanol (biodiesel) is led by corn (German diesel) even at high frequencies (low scales), which implies that the biofuels prices react more rapidly to the changes in their producing factors.

14/01099 Transesterification of soybean oil to biodiesel using zeolite supported CaO as strong base catalysts

Wu, H. *et al. Fuel Processing Technology*, 2013, 109, 13–18.

A series of supported CaO catalysts with NaY, KL and NaZSM-5 zeolites as supports were prepared by microwave irradiation and used to catalyse the transesterification of methanol with soybean oil. The activities of synthesized catalysts were investigated compared to pure CaO. It was found that the activity of CaO catalyst increased after supported on zeolites, and the CaO/NaY exhibited the best performance. The improved catalytic activity was attributed to the increase of BET values and the concomitant increase of basic strength and basicity after dispersed on NaY zeolite through microwave irradiation. The prepared catalysts were characterized by several techniques such as X-ray diffraction, Brunauer–Emmett–Teller surface area, scanning electron microscopy and the Hammett indicator method. In addition, the factors affecting biodiesel yield were investigated to optimize the reaction conditions. A biodiesel yield of 95% was achieved (using the CaO/NaY catalyst) with 30 wt% of CaO loading on NaY zeolite, methanol/soybean oil molar ratio of 9, reaction temperature of 65 °C, reaction time of 3.0 h and a catalyst/oil mass ratio of 3%. The results indicated that the supported catalyst had the capacity of water resistance and acid resistance. A high yield (more than 80%) could be obtained when the acid value and the water content of oil were less than 4 mg KOH/g and 1.5%, respectively.

14/01100 Transforming biogas into biomethane using membrane technology

Scholz, M. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 199–212.

Upgrading biogas, i.e. the removal of CO_2 from CH_4 is an attractive regenerative energy as it is supplied continuously. Conventional upgrading techniques such as absorption or adsorption require significant amounts of energy and require equipment of large size. Hence, this study gives an overview on gas permeation membrane processes which are applied in biogas upgrading. Here, the authors consider the upgrading process as a whole. The multiscale design of membrane-based gas separation is analysed in detail. Membrane materials, gas permeation modules and their respective operation as well as gas permeation processes for biogas upgrading are investigated. Applying gas permeation modules, compression of the feed gas should be used since it is energy efficient for gases with high amounts of CO_2. Single stage gas permeation processes are not able to produce a high CH_4 purity and simultaneously obtain a high CH_4 recovery. Hence, multistage concepts are mandatory. Membrane-based upgrading systems are an interesting alternative to conventional biogas upgrading equipment and it is expected that they will significantly contribute to future energy supplies.

14/01101 Why large-scale bioenergy production on marginal land is unfeasible: a conceptual partial equilibrium analysis

Bryngelsson, D. K. and Lindgren, K. *Energy Policy*, 2013, 55, 454–466.

A transparent and conceptual partial equilibrium model of global land use is used to explore long-term effects of large-scale introduction of bioenergy, under different policy cases. The transparency of the model, and the consideration of clear-cut policies, provides a clear picture of how main mechanisms of land-use competition work, and how they influence the food and bioenergy systems. The model is subjected to a detailed characterization, in which parameters critical to the results and conclusions are detected and their impacts depicted. A large-scale introduction of bioenergy would raise food prices in all cases/scenarios investigated, and relative price increases of extensively produced crops would be at least twice as high as compared to intensively produced crops. Banning production of bioenergy from the most productive land (limiting production to 'marginal land') would reduce this price impact. However, the authors show that bioenergy is unlikely to ever be produced on any commercial scale only on land of low productivity. The economic incentives would be strong for owners of more productive land to grow bioenergy anyway and out-compete the more costly production on low yielding land. Large-scale deforestation would become attractive in response to increased bioenergy demand, especially for extensive production systems such as grazing.

Geothermal energy

14/01102 A comparative study on conventional and advanced exergetic analyses of geothermal district heating systems based on actual operational data

Hepbasli, A. and Keçebaş, A. *Energy and Buildings*, 2013, 61, 193–201.

This paper comparatively evaluates exergy destructions of a geothermal district heating system (GDHS) using both conventional and advanced exergetic analysis methods to identify the potential for improvement and the interactions among the components. As a real case study, the Afyon GDHS in Afyonkarahisar, Turkey, is considered based on actual operational data. For the first time, advanced exergetic analysis is applied to the GDHSs, in which the exergy destruction rate within each component is split into unavoidable/avoidable and endogenous/exogenous parts. The results indicate that the interconnections among all the components are not very strong. Thus, one should focus on how to reduce the internal inefficiency (destruction) rates of the components. The highest priority for improvement in the advanced exergetic analysis is in the re-injection pump (PM-IX), while it is the heat exchanger (HEX-III) in the conventional analysis. In addition, there is a substantial influence on the overall system as the total avoidable exergy destruction rate of the heat exchanger (HEX-V) has the highest value. On the overall system basis, the value for the conventional exergetic efficiency is determined to be 29.29% while that for the modified exergetic efficiency is calculated to be 34.46% through improving the overall components.

14/01103 A novel three-dimensional transient model for subsurface heat exchange in enhanced geothermal systems

Jiang, F. *et al. International Communications in Heat and Mass Transfer*, 2013, 41, 57–62.

Understanding the subsurface heat exchange process in enhanced geothermal systems (EGS) is crucial to the efficiency of heat extraction and the sustainable utilization of geothermal reservoir. The authors develop a novel three-dimensional transient model for the study of the subsurface heat exchange process in EGS. The novelty of this model is embodied by a couple of salient features. First, the geometry of interest physically consists of multiple domains: open channels for injection and production wells, the artificial heat reservoir, and the rock enclosing the heat reservoir, while computationally the authors treat it as a single-domain of multiple sub-regions associated with different sets of characteristic properties (porosity and permeability, etc.). This circumvents typical difficulties about matching boundary conditions between sub-domains in traditional multi-domain approaches and facilitates numerical implementation and simulation of the complete subsurface heat exchange process. Second, the heat reservoir is treated as an equivalent porous medium of a single porosity, while the study considers thermal non-equilibrium between solid and fluid components and introduces two sets of heat transfer equations to describe the heat advection and conduction for fluid in rock apertures and the heat conduction in rock matrix, respectively, thus enabling the simulation and analysis of convective heat exchange between rock matrix and fluid flowing in the apertures. A case study with respect to an imaginary EGS demonstrates the validity and capability of the developed model.

14/01104 A passive design strategy for a horizontal ground source heat pump pipe operation optimization with a non-homogeneous soil profile

Rezaei-Bazkiaei, A. *et al. Energy and Buildings*, 2013, 61, 39–50.

The effectiveness of a non-homogeneous soil profile for horizontal ground source heat pumps, defined as natural backfill with an intermediate layer of material having different thermal characteristics, is investigated. Steps toward development of a comprehensive model to consider the effects of the non-homogeneous layer are described. The developed model is utilized successfully in conjunction with a genetic algorithm (GA) search method to obtain the optimized operational parameters for a ground source heat pump in three different climate conditions. A properly sized and engineered non-homogeneous soil profile demonstrated the potential to increase the energy extraction/dissipation rates from/to the ground to a significant level. The potential benefit of a recycled product, tyre-derived aggregate (TDA), as an insulating non-homogeneous layer is assessed. TDA is demonstrated to be more effective in the cold climate (Buffalo) by increasing the energy extraction rates from the ground approximately 15% annually. TDA's effectiveness is less pronounced in a relatively moderate climate (Dallas) by increasing the energy extraction rates from the ground about 4% annually. For the cooling only scenario (Miami), a high conductive intermediate layer of saturated sand exhibited greater potential to increase the energy dissipation to the ground.

14/01105 A simplified model of energy pile for ground-source heat pump systems

Lee, C. K. and Lam, H. N. *Energy*, 2013, 55, 838–845.

A simplified three-dimensional finite difference model for a single cylindrical energy pile (CEP) was developed. The present model was first verified with an analytical solution based on the special case that the material inside and outside the CEP had the same thermal properties. For the case of different thermal properties in the various ground regions, the calculated thermal resistance of the CEP (R_{ep}) under a constant applied load was compared with the one determined with the assumption of a steady state inside the CEP. In both situations, the differences were found to be small. The effect of the thermal properties of various regions on the performance of the CEP was investigated. It was found the material underneath the CEP had negligible impact on the CEP performance. The soil material outside the CEP had stronger effect on the fluid temperature leaving the CEP ($T_{f,\ out}$) while R_{ep} depended more on the material inside the CEP. Meanwhile, R_{ep} reached a higher value at the beginning of each load cycle. The influence became significant for intermittent loading of the

CEP. Furthermore, it was found that for optimal design involving a single pipe circuit inside the CEP, all pipes should be equally-spaced and connected consecutively.

14/01106 Economic analysis of exergy efficiency based control strategy for geothermal district heating system

Keçebaş, A. and Yabanova, I. *Energy Conversion and Management*, 2013, 73, 1–9.

The exergy efficiency-based control strategy (ExEBCS) for exergy efficiency maximization in geothermal district heating systems (GDHSs) is economically evaluated in this study. As a real case study, the Afyon GDHS in the city of Afyonkarahisar, Turkey, was considered. Its actual thermal data as of average weekly data were collected in heating seasons during the period 2006–2010 for artificial neural network (ANN) modelling. The ANN modelling of the Afyon GDHS was used as a test system to demonstrate the effectiveness and economic impact of the ExEBCS under various operating conditions. Then, the ExEBCS was evaluated economically in case of application to real Afyon GDHS of the ExEBCS. The results show that the initial cost for the ExEBCS was more expensive than that for the old one by $633,000/year as a result of replacing automatic controller. The saving in heat production makes the ExEBCS profitable by up to 7% of annual energy saving as a result of the increase in the heat production by 88% when the control system is operated. This results in a short payback period of 3.8 years. This study confirms the suitability of the ExEBCS in district heating systems (especially GDHS).

14/01107 Experimental investigation on the operation performance of a direct expansion ground source heat pump system for space heating

Wang, H. *et al. Energy and Buildings*, 2013, 61, 349–355.

This paper describes a small-scale experimental direct-expansion ground source heat pump system in typical clay soils for space heating of a building in Jinzhou, China. It uses R22 as the refrigerant, consisting of four single U-shaped copper ground heat exchangers with a uniform depth of 20 m. A special circular bend is designed on the copper tube to enhance the lubricant oil return of the scroll compressor. The operation performance and energy efficiency of the DX-GSHP system is tested in the heating mode. Results show that the present DX-GSHP system is reliable and effective. During the heating period, when the heating capacity of the indoor fan coil is 6.41 kW, the room temperature varies from 18 to 20 °C even if the door is opened or closed frequently. The average COP of the heat pump unit and the whole DX-GSHP system are 3.12 and 2.88, respectively, and the average heat-transfer rate of GHEs per depth is 54.4 W/m. In addition, the influence of the opening of the electronic expansion valve on the operation performance is analysed. The present results can provide useful guides for the design and further improvement of DX-GSHP systems under similar geological conditions.

14/01108 Feasibility of combined solar thermal and ground source heat pump systems in cold climate, Canada

Rad, F. M. *et al. Energy and Buildings*, 2013, 61, 224–232.

This document presents a study for examining the viability of hybrid ground source heat pump (GSHP) systems that use solar thermal collectors as the supplemental component in heating dominated buildings. Loads for an actual house in the City of Milton near Toronto, Canada, were estimated. TRNSYS, a system simulation software tool, was used to model yearly performance of a conventional GSHP system as well as a proposed hybrid GSHP system. Actual yearly data collected from the site were examined against the simulation results. This study demonstrates that hybrid ground source heat pump system combined with solar thermal collectors is a feasible choice for space conditioning for heating dominated houses. It was shown that the solar thermal energy storage in the ground could reduce a large amount of ground heat exchanger (GHX) length. Combining three solar thermal collectors with a total area of 6.81 m^2 to a GSHP system will reduce GHX length by 15%. Sensitivity analysis was carried out for different cities of Canada and resulted that Vancouver, with mildest climate compared to other cities, was the best candidate for the proposed solar hybrid GSHP system with a GHX length reduction to solar collector area ratio of 7.64 m/m^2. Overall system economic viability was also evaluated using a 20-year life-cycle cost analysis. The analysis showed that there is small economic benefit in comparing to the conventional GSHP system. The net present value of the proposed hybrid system based on the 20-year life-cycle cost analysis was estimated to be in a range of 3.7%–7.6% (or Can$1500–3430) lower than the conventional GSHP system depending on the drilling cost.

14/01109 Geothermal activities in the Main Ethiopian Rift: hydrogeochemical characterization of geothermal waters and geothermometry applications (Dofan-Fantale, Gergede-Sodere, Aluto-Langano)

Pürschel, M. *et al. Geothermics*, 2013, 47, 1–12.

Ethiopia holds an enormous capacity to generate geothermal energy in the volcano-tectonically active zones of the East African Rift System. This study investigates the potential of three geothermal prospect areas in the Main Ethiopian Rift (Dofan-Fantale, Gergede-Sodere, Aluto-Langano). The authors examine existing and new data from a water sampling campaign, both of which are evaluated in terms of geochemistry and applicability for the estimation of geothermal subsurface temperatures. Several solute geothermometers, Cl–SO_4–HCO_3 and Na–K–Mg ternary diagrams as well as silica-enthalpy and chloride-enthalpy mixing models were applied to the prevailing alkaline and Na–HCO_3 or Na–Cl–HCO_3 dominated waters. Mixing was most pronounced in the individual subregions of Dofan-Fantale and Gergede-Sodere, yet these areas still indicate high heat-generating capabilities. The applied enthalpy-chloride mixing model suggests a subsurface temperature of 190 ± 20 °C for these hot springs. This temperature estimate is in good agreement with those obtained from the Na–K and Na–K–Ca geothermometers (185 ± 20 °C) for both geothermal areas. Additionally, for Gergede-Sodere it agreed well with the silica-enthalpy mixing model hot spring water results with the assumption that steam loss occurs before mixing (170 ± 20 °C). Furthermore, the enthalpy-chloride mixing model refers to reservoir temperatures between 300 °C and 370 °C for the Aluto-Langano geothermal fluids, which are in the same magnitude than the ones obtained by the silica-enthalpy mixing model for hot springs, if no steam loss occurs before mixing (270 ± 30 °C). In addition, they are comparable with few known data collected in drilled wells in the Aluto-Langano geothermal field (231–282 °C for LA-4 and LA-8 as well as 315–363 °C for LA-3 and LA-6).

14/01110 Geothermal double-flash plant with interstage reheating: an updated and expanded thermal and exergetic analysis and optimization

DiPippo, R. *Geothermics*, 2013, 48, 121–131.

The concept of a double-flash geothermal power plant with an interstage reheater is updated and extended. The conceptual plant holds a thermodynamic performance advantage over a conventional double-flash plant over the range of reservoir temperatures studied from 220 to 320 °C, with the advantage increasing as the temperature increases. An exergy assessment is performed on the whole plant with a detailed examination of the reheater. The effect on performance of the terminal temperature difference in the reheater is found to be small. The trend in performance of the new plant is determined as a function of rising wellhead quality in the event that the reservoir begins to ‘dry out’ yielding higher steam fractions at the wellhead. The potential for silica scaling in the lower-temperature components is examined and found to be of concern. The exact optimized separator and flash temperatures are compared to the simple rule-of-thumb, the ‘equal-temperature-split’ rule, which turns out to be quite accurate. A conventional double-flash plant using a turbine designed to remove moisture after each stage is also examined and found to be theoretically roughly equal to the conceptual plant in terms of power performance. The extra power that can be generated by a reheat plant is monetized to compare with the extra cost involved in the more complex plant relative to a conventional double-flash plant. The projected payback is relatively short indicating that the proposed plant should be both thermodynamically and economically worthwhile on condition that some means of controlling silica precipitation is adopted.

14/01111 Heat transfer model and design method for geothermal heat exchange tubes in diaphragm walls

Sun, M. *et al. Energy and Buildings*, 2013, 61, 250–259.

The technology of embedding heat exchange tubes in diaphragm walls is a new direction for ground-coupled heat pumps (GCHP). This paper examines the heat transfer model and design method for geothermal heat exchangers in diaphragm walls, which are seldom investigated in the world. Two-dimensional heat transfer models for diaphragm wall heat exchangers (DWHE) are established. A design method for DWHE is further developed to calculate the hourly heat exchange capacity of DWHE and to get the reasonable design parameter of DWHE. The DWHE model over the excavation line has the same changing trend with numerical solutions, and the relative errors between them are less than 2%. The relative errors of calculated heat exchange rate per metre using DWHE model and measured data are less than 6% after running 10 h. The relative errors of temperature between DWHE model under the excavation line and the measured data at different positions are no more than 9%, whereas the relative error between the tradition models in GCHP (line source model and finite-line source model) and the measured data may reach as much as 40%.

14/01112 Las Pailas geothermal binary power plant, Rincón de la Vieja, Costa Rica: performance assessment of plant and alternatives

DiPippo, R. and Moya, P. *Geothermics*, 2013, 48, 1–15.

A technical assessment is provided of the 35 MW (net) binary power plant at the Las Pailas geothermal field, along with three alternative designs including a simple single-flash plant and a single-flash plant combined with a bottoming binary cycle, both with and without a recuperator. The status and characteristics of the wells, the gathering system, and plant/well field layout are presented. The best producing well is the northernmost one, PGP-17, close to the Rincon de la Vieja National Park; at a wellhead pressure of 8 bar,a, it produces about 135 kg/s total flow of which about 25 kg/s is steam. The unique design of the two-unit binary power plant is discussed in detail. Plant performance is assessed based on the design specifications. Thermal and utilization efficiencies are calculated for the plant, the power cycle, the major components, as well as for the three alternative designs. Under design conditions, the Las Pailas plant has a thermal efficiency of 15.1%, a second law efficiency of 37.2% based on the incoming exergy of the geofluid, and a second law efficiency of 51.2% based on the change in exergy of the geofluid as it passes through the plant. The results of the acceptance test are presented. The analysis of data for the first 15 months of plant operation indicates that the average plant (or capacity) factor was 89.9% and the plant was available and generating power 91.6% of the time. Among the alternative designs considered, the one with the highest power output for the same geofluid inlet conditions as the actual plant was a single-flash plant optimized for peak power using the existing six production well flow curves. That alternative generated about 9.6 MW-gross more than the gross power of the actual plant, albeit at a slightly lower utilization efficiency. The highest utilization efficiency was achieved with a single-flash plant combined with a bottoming binary plant, either with or without a recuperator. No attempt was made to estimate the installed costs of the alternatives since no data were available on the actual cost to install the Las Pailas plant.

14/01113 Methodologies for analysis of productivity decline: a review and application

Aragón-Aguilar, A. *et al. Geothermics*, 2013, 48, 69–79.

This work emphasizes the convenience of combining several methodologies to assess decline analysis in wells. The authors show that using different techniques, the reservoir characterization diagnoses are reinforced. Four of the different methods associated to decline analysis in well productivity are shown. The governing equations, used in methodologies of analysis decline, normalized flow and increase of the damage effect, were reviewed. The diagnosis applied to identify the decline model type, using the classical methodology of analysis, was shown. The comparison between predicted and measured values using normalized flow methodology provides reliable results. Through determining the damage effect technique it was found a direct correlation between the productivity decline and the increase in damage value along the productive life of the well. Geochemical variations in fluids can also provide support in decline rate studies of wells. The methodologies reviewed in this work help in looking for integral solutions to improve the reservoirs productivity.

14/01114 Mixtures of SF_6–CO_2 as working fluids for geothermal power plants

Yin, H. *et al. Applied Energy*, 2013, 106, 243–253.

In this paper, supercritical/transcritical thermodynamic cycles using mixtures of sulfur hexafluoride (SF_6)–carbon dioxide (CO_2) as working fluids were investigated for geothermal power plants. The system of equations that described the thermodynamic cycle was solved using a Newton–Raphson method. This approach allows a high computational efficiency even when thermophysical properties of the working fluid depend strongly on the temperature and pressure. The thermophysical properties of the mixtures were obtained from National Institute of Standards and Technology REFPROP software and constituent cubic equations. The local heat transfer coefficients in the heat exchangers were calculated based on the local properties of the working fluid, geothermal brine, and cooling water. The heat exchanger areas required were calculated. Numerical simulation results presented for different cycle configurations were used to assess the effects of the SF_6 fraction in CO_2, brine temperature, and recuperator size on the cycle thermal efficiency, and size of heat exchangers for the evaporator and condenser. For working fluids with SF_6, concentrations of 15 and 20 mol% were found to yield the highest Brayton and Rankine cycle efficiencies, respectively.

14/01115 Numerical investigation of double diffusive natural convection of CO_2 in a brine saturated geothermal reservoir

Islam, A. W. *et al. Geothermics*, 2013, 48, 101–111.

In geologic sequestration or in CO_2-based geothermal systems, CO_2 is present on top of the brine phase. This study performed a numerical analysis of a geothermal reservoir that is impermeable from the sides and is open to CO_2 at the top. For this configuration, double diffusive natural convection due to density and temperature differences across the height enhance the mass transfer rate of CO_2 into the initially stagnant brine. The analysis is done using mass, momentum, energy conservation laws, and the Darcy laws. The objective is to understand the diffusion of CO_2 over long periods of time after sequestration into a subsurface porous media geothermal aquifer. The problem parameters are the solutal Rayleigh number ($100 \le Ra_s \le 10{,}000$), the buoyancy ratio ($2 \le N \le 100$), the cavity aspect ratio ($0.5 \le A \le 2$), and a fixed Lewis number ($Le = 301$). Numerical computations do not exhibit natural convection effects for homogeneous initial conditions. Hence a sinusoidal perturbation is added for the initial top boundary condition. It is found that the CO_2 plumes move faster when Ra_s is increased, however they slow down with decreasing N. For every simulation run, the average CO_2 concentration ($\bar{S} = (\sum_i^{n_i} \sum_j^{n_j} c_{i,j}/n_i \times n_j)$ is computed. Higher concentration rates in laterally wide reservoirs make better candidates than deeper aquifers for CO_2 sequestration.

14/01116 Numerical studies on power generation from co-produced geothermal resources in oil fields and change in reservoir temperature

Gong, B. *et al. Renewable Energy*, 2013, 50, 722–731.

The effects of injection rate and the temperature of injected (or re-injected) water on reservoir temperature during power generation by utilizing hot fluids co-produced from oil and gas field were studied using a numerical simulation approach. The chosen target reservoir was LB oil reservoir from Huabei oil field. The reservoir temperature was about 120 °C. It has been found that there was significant temperature decline if the water injection rate was greater than a specific value and the temperature of injected water was less than a specific value. Also studied were the effect of water injection rate on oil production and water cut in LB oil reservoir. The results demonstrated that the oil production increased with the water injection rate, which is reasonable and would be helpful to conduct the power generation project in LB oil reservoir from the economic point of view.

14/01117 Optimization of injection scheduling in fractured geothermal reservoirs

Juliusson, E. and Horne, R. N. *Geothermics*, 2013, 48, 80–92.

This paper describes a method for optimizing injection rates in fractured geothermal reservoirs. The optimization approach suggested here is based on maximizing the net present value (NPV) of production revenue from the reservoir. The method relies on tracer and flow-rate data, which are used to calibrate a thermal transport model in such a way that the thermal drawdown depends on the injection rates. Then, an empirical correlation is used to relate the injection and production temperature to the specific electrical power output. The power output model, in conjunction with predictions for the future energy prices and interest rates, allows the computation of the NPV as a function of the injection rates. This characterization of the problem makes it possible to solve it quickly and efficiently. The optimization method was applied to two discrete-fracture reservoir simulation models. The first having a relatively simple structure with two injectors and two producers and the second being a more complex model with seven wells and a fracture structure based on observations from the Soultz-sous-Forêts enhanced geothermal system in France. The results show that the method works well for both the simple and more complex case. A finding of particular interest is that the optimal injection schedule depends strongly on the minimum design temperature for the power plant.

14/01118 Performance analysis of electricity generation by the medium temperature geothermal resources: Velika Ciglena case study

Rašković, R. *et al. Energy*, 2013, 54, 11–31.

During the last decade, a design of an energy efficient and cost effective geothermal plant represents a significant and on-going technical challenge in all the Western Balkan countries. In the Republic of Croatia, the geothermal field Velika Ciglena is identified as one of the most valuable geothermal heat sources and probably the location where the first geothermal plant in the Western Balkan area will be built. The purpose of this work is the conceptual design and performance analysis of the binary plants – the one which operates under the organic Rankine cycle (ORC) and the other under Kalina cycle – which can be used for geothermal energy utilization in Velika Ciglena. A conceptual plant design is performed by the equation-oriented modelling approach and supported by the two steady-state spreadsheet simulators. The performance analysis of all design solutions is conducted through energy and exergy analysis, and by the estimated total cost of operating units in the plant. The results of the analysis indicate that the plant design based on the ORC cycle has a higher thermodynamic efficiency and lower cost of equipment, and consequently, it is more suitable for the future geothermal plant in Velika Ciglena.

14/01119 Regional application of ground source heat pump in China: a case of Shenyang

Geng, Y. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 95–102.

Rapid industrialization, increasing population urbanization, and improved living standards have all contributed to greatly increasing greenhouse gas (GHG) emissions in urban areas of developing countries. This situation is especially true for China, where fossil fuel depletion is a critical issue from its contribution to GHG emissions, and in terms of resources being consumed. To address these issues the Chinese government has supported application of ground source heat pumps (GSHP) technology. This focus is meant to alleviate the dependence on fossil fuels and improve the country's energy structure. Several Chinese cities have embraced GSHP technology, and currently achieved some results. Shenyang, in Liaoning province, is one pioneering municipality. The city has become a champion of GSHP projects. However, the international energy research community has not been made aware of this important regional effort. The aim of this paper is to introduce and review the progress of GSHP technology diffusion within this region of China. This practical review will include policies, benefits and challenges facing the region and their adoption of GSHP technology. Recommendations for improvement of regional application on GSHP technologies given regional conditions are also made. These recommendations include strong leadership, appropriate policy incentives, effective enforcement mechanisms, and roundtable-based management. Relevant experience and lessons learned can be shared by other, globally locations, to help in GSHP technology diffusion.

14/01120 Risk analysis of geothermal power plants using failure modes and effects analysis (FMEA) technique

Feili, H. R. *et al. Energy Conversion and Management*, 2013, 72, 69–76.

Renewable energy plays a key role in the transition toward a low carbon economy and the provision of a secure supply of energy. Geothermal energy is a versatile source as a form of renewable energy that meets popular demand. Since some geothermal power plants (GPPs) face various failures, the requirement of a technique for team engineering to eliminate or decrease potential failures is considerable. Because no specific published record of considering a failure modes and effects analysis (FMEA) applied to GPPs with common failure modes has been found, in this paper, the utilization of FMEA as a convenient technique for determining, classifying and analysing common failures in typical GPPs is considered. As a result, an appropriate risk scoring of occurrence, detection and severity of failure modes and computing the risk priority number for detecting high potential failures is provided. In order to expedite accuracy and ability to analyse the process, XFMEA software is used. Moreover, five major parts of a GPP are studied to propose a suitable approach for developing GPPs and increasing reliability by recommending corrective actions for each failure mode.

14/01121 Seismic Vp and Vp/Vs structure of the geothermal area around Tarutung (North Sumatra, Indonesia) derived from local earthquake tomography

Muksin, U. *et al. Journal of Volcanology and Geothermal Research*, 2013, 260, 27–42.

A passive seismic experiment with 42 short-period stations was setup for 10 months from May 2011 within a 20–30 km radius covering the Tarutung basin and the northern part of the Sarulla graben along the seismically active Sumatran fault (North Sumatra, Indonesia). The objective of the project is to investigate the geothermal setting based on the Vp and Vp/Vs structures and the distribution of seismicity. The authors recorded 2856 local earthquakes by at least eight stations which were reduced to 809 events having gap angle less than 180°. The initial earthquake locations were determined using simultaneous inversion for hypocentres and one-dimensional velocity structure followed by three-dimensional tomographic inversion. The resulting seismicity distribution, Vp and Vp/Vs structure reveal systematic differences between the Tarutung basin and the Sarulla graben. The Tarutung pull-apart basin is characterized by a complex structure reflected by a broader distribution of seismicity compared with the very narrow, rather vertical hypocentre distribution in the Sarulla graben, which was formed by fault-perpendicular extension and not by pull-apart tectonics. High Vp/Vs values near to the surface are imaged within the Sarulla graben and north-east of the Tarutung basin. These features are interpreted as fluid bearing sediments with fracturing indicating potentially favourable conditions for geothermal exploitation. The localized fluid flow northeast of Tarutung could be explained by the releasing step-over structure of the pull-apart basin and resulting dilatational stress regime in this part of the basin. Heat sources are assumed to be located at greater depth in association with magmatic activities accompanying the subduction process, and the heat is transported along the Sumatran fault to shallow depth.

14/01122 Self-superheating: a new paradigm for geothermal power plant design

Mathieu-Potvin, F. *Geothermics*, 2013, 48, 16–30.

In this paper, a new thermodynamic concept for improving the single-flash and the double-flash cycles in geothermal power plants is presented. This process, named self-superheating, uses a part of the heat contained in the geothermal fluid at the well-head to increase the temperature of the steam that enters the turbines. When optimal separator temperature is used, the results of this novel process are an increase of the specific output (approximately 5%) of the geothermal power plant and a reduction (approximately 20–40%) of the liquid content in the last stages of the turbines. The optimal separator temperature for the cycles using Self-Superheating is about 5 °C lower than the optimal separator temperature of the single-flash and double-flash cycles. The simple but fundamental process of Self-Superheating opens the route for more complex thermodynamic cycles in geothermal power plants.

14/01123 Simulation of thermal performance of horizontal slinky-loop heat exchangers for ground source heat pumps

Chong, C. S. A. *et al. Applied Energy*, 2013, 104, 603–610.

This paper presents results obtained from a numerical simulation for the horizontal slinky-loop heat exchanger of a ground-source heat pump system. A three-dimensional numerical model was developed and the results of the thermal performance of various heat exchanger configurations are presented. The investigation was carried out on five types of loop pitch (loop spacing), three types of loop diameter, three values of soil thermal properties, and allowing continuous and intermittent operation. Comparison was made for the heat transfer rate, the amount of pipe material needed, as well as excavation work required for the horizontal slinky-loop heat exchanger. The results indicate that system parameters have a significant effect on the thermal performance of the system.

Solar energy

14/01124 A fast and effective local search algorithm for optimizing the placement of wind turbines

Wagner, M. *et al. Renewable Energy*, 2013, 51, 64–70.

The placement of wind turbines on a given area of land such that the wind farm produces a maximum amount of energy is a challenging optimization problem. This study tackles the problem, taking into account wake effects that are produced by the different turbines on the wind farm. This significantly improves upon existing results for the minimization of wake effects by developing a new problem-specific local search algorithm. One key step in the speed-up of the algorithm is the reduction in computation time needed to assess a given wind farm layout compared to previous approaches. The new method allows the optimization of large real-world scenarios within a single night on a standard computer, whereas weeks on specialized computing servers were required for previous approaches.

14/01125 A model of competition in the solar panel industry

Pillai, U. and McLaughlin, J. *Energy Economics*, 2013, 40, 32–39.

This study developed a model of competition in the solar panel industry. Solar firms manufacture panels that are differentiated both vertically and horizontally, and compete by setting quantities. The equilibrium of the model is consistent with a set of stylized facts that were documented, including variation in prices, mark-ups and market shares across firms. The authors calibrated the model using a new dataset data on prices, costs and shipments of leading solar companies, as well as solar sales in four leading markets. The calibrated model is applied to evaluate the impact of a decline in the price of polysilicon, a key raw material used in the manufacture of solar panels, on the equilibrium price of solar panels.

14/01126 A neural network-based optimizing control system for a seawater-desalination solar-powered membrane distillation unit

Porrazzo, R. *et al. Computers & Chemical Engineering*, 2013, 54, 79–96.

Several schemes have been proposed so far for coupling desalination processes with the use of renewable energy. One of their main drawbacks, however, is the nature of the energy source that requires a discontinuous and non-stationary operation, with some control and optimization problems. In this study, a solar powered membrane distillation system has been used for developing an optimizing control strategy. A neural network (NN) model of the system has been trained and tested using experimental data purposely collected. Afterwards, the NN model has been used for the analysis of the process performance under various operating conditions, namely distillate production versus feed flow rate, solar radiation and cold feed temperature. On this basis, a control system that optimizes the distillate production under variable operating conditions has been developed, implemented and tested.

14/01127 A new method for determining the characteristics of solar cells

Peng, L. *et al. Journal of Power Sources*, 2013, 227, 131–136.

A new method is proposed to describe the characteristics of solar cell and module in this article. By using the exact explicit analytical solutions, the current–voltage and power–voltage curves of the corresponding modules are calculated and simulated. In order to extract the parameters of the solar cells, an optimized technique is presented by using Lambert *W* function and polynomial curve fitting. The accuracy of the model is compared with previous methods in other work. Results have the good agreement between the fitted current–voltage curves and the experimental data. Moreover, error and statistical analyses are carried out to illustrate the accuracy of the estimated parameters and procedure suitability.

14/01128 A review of the applications of nanofluids in solar energy

Mahian, O. *et al. International Journal of Heat and Mass Transfer*, 2013, 57, (2), 582–594.

Utilizing nanofluids as an advanced kind of liquid mixture with a small concentration of nanometre-sized solid particles in suspension is a relatively new field, which is less than two decades old. The aim of this review paper is the investigation of the nanofluids' applications in solar thermal engineering systems. The shortage of fossil fuels and environmental considerations motivated the researchers to use alternative energy sources such as solar energy. Therefore, it is essential to enhance the efficiency and performance of the solar thermal systems. Nearly all of the former works conducted on the applications of nanofluids in solar energy is regarding their applications in collectors and solar water heaters. Therefore, a major part of this review paper allocated to the effects of nanofluids on the performance of solar collectors and solar water heaters from the efficiency, economic and environmental considerations viewpoints. In addition, some reported works on the applications of nanofluids in thermal energy storage, solar cells, and solar stills are reviewed. Subsequently, some suggestions are made to use the nanofluids in different solar thermal systems such as photovoltaic/thermal systems, solar ponds, solar thermoelectric cells, and so on. Finally, the challenges of using nanofluids in solar energy devices are discussed.

14/01129 An efficient fault diagnosis method for PV systems based on operating voltage-window

Gokmen, N. *et al. Energy Conversion and Management*, 2013, 73, 350–360.

With the increasing use of photovoltaic (PV) systems, the research studies to improve the efficiency of PV systems have gained greater interest in recent years, especially under non-uniform operating conditions. However, there is a little attention on fault diagnosis of PV arrays. This paper develops and demonstrates a method that can efficiently detect the number of open and short circuit faults and discriminate between them and partial shading conditions. This method is based on only the measurement of operating voltage of PV string and ambient temperature. In that manner, the proposed method takes into consideration of the minimum number of sensors to reduce the cost of the system, as one of the main purposes of this study. The simulation and experimental results are presented to demonstrate the effectiveness of the proposed method under both uniform and non-uniform irradiance conditions.

14/01130 Characterization of PV panel and global optimization of its model parameters using genetic algorithm

Ismail, M. S. *et al. Energy Conversion and Management*, 2013, 73, 10–25.

This paper details an improved modelling technique for a photovoltaic (PV) module; utilizing the optimization ability of a genetic algorithm, with different parameters of the PV module being computed via this approach. The accurate modelling of any PV module is incumbent upon the values of these parameters, as it is imperative in the context of any further studies concerning different PV applications. Simulation, optimization and the design of the hybrid systems that include PV are examples of these applications. The global optimization of the parameters and the applicability for the entire range of the solar radiation and a wide range of temperatures are achievable via this approach. The manufacturer's data sheet information is used as a basis for the purpose of parameter optimization, with an average absolute error fitness function formulated; and a numerical iterative method used to solve the voltage-current relation of the PV module. The results of single-diode and two-diode models are evaluated in order to ascertain which of them are more accurate. Other cases are also analysed in this paper for the purpose of comparison. The Matlab–Simulink environment is used to simulate the operation of the PV module, depending on the extracted parameters. The results of the simulation are compared with the data sheet information, which is obtained via experimentation in order to validate the reliability of the approach. Three types of PV modules, using different technologies, were tested for the purpose of this validation, and the results confirm the accuracy and reliability of the approach developed in this study. The effectiveness of the model developed by this approach to predict the performance of the PV system under partial shading conditions was also validated.

14/01131 Computation of irradiance in a solar still by using a refined algorithm

Madhlopa, A. and Clarke, J. A. *Renewable Energy*, 2013, 51, 13–21.

A refined solar algorithm from the ESP-r system has been used to calculate the distribution of solar irradiation inside a basin-type solar still. In the approach, surface finish, view factors and multiple reflections are taken into consideration in the computation of the solar radiation that reaches the surface of the saline water in the distillation system. The algorithm was applied to a solar still tested at the University of Strathclyde in Glasgow (55°52′N, 4°15′W). Under the prevailing meteorological conditions, it was found that previous models overestimated the computed solar load on the saline water surface. The present modelling approach is demonstrated to exhibit a higher degree of accuracy than previous methods for irradiance distribution prediction, yielding new insights into approaches to solar still performance improvement. The modelling outcomes are presented and discussed.

14/01132 Effective utilization of unified power quality conditioner for interconnecting PV modules with grid using power angle control method

Palanisamy, K. *et al. International Journal of Electric Power & Energy Systems*, 2013, 48, 131–138.

This paper proposes the effective utilization of unified power quality conditioner (UPQC) for interconnecting the PV modules to the grid using power angle control (PAC) method. A shunt active power filter (APF) is used to evacuate the power from the photovoltaic module in addition to compensating the current harmonics, load unbalance and reactive power. To accomplish this the series APF in the UPQC is used for supplying a part or whole reactive power required by the load in addition to compensating the sag, swell, supply voltage unbalance and distortions. This is made possible by controlling the phase angle and magnitude of series injected voltage called power angle control method. The reactive power and voltage compensation technique introduces a phase shift between the load terminal voltage and source voltage. The transient due to sudden phase shift is minimized using step-by-step introduction of series compensation voltage. The proposed method effectively utilizes the shunt APF and series APF in the UPQC for interconnecting the PV module to the grid. The simulation results from MATLAB/SIMULINK are discussed to validate the developed method.

14/01133 Evaluation of finite volume solutions for radiative heat transfer in a closed cavity solar receiver for high temperature solar thermal processes

Martinek, J. and Weimer, A. W. *International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 585–596.

High temperature solar-thermal reaction processes can be carried out within closed-cavity solar receivers in which concentrated solar energy enters the cavity through a small aperture or window and is absorbed either directly by reactants or by tubes containing reactant mixtures. Accurate modelling of radiation transfer phenomena in the solar receiver is critical for predicting receiver performance and improving receiver design. The accuracy of the finite volume (FV) method is evaluated in comparison to Monte Carlo (MC) techniques for both the concentrated solar energy and the energy emitted by heated surfaces in a receiver with either absorbing/diffusely emitting or specularly reflective cavity walls. Models are solved for two-dimensional slices of each of two receiver configurations with four spatial grids ranging from 2300 to 133,000 mesh elements, and three different angular grids. Solar radiative energy is described by a simplified uniform spatial profile at the receiver aperture that is either collimated or diffuse. Quantitatively accurate FV solutions for the solar energy either require highly refined angular and spatial grids, or are not possible on the mesh sizes investigated in this study. FV solutions for the emitted energy are sufficient even on coarse angular and spatial grids. FV solutions are least accurate when the cavity is highly specularly reflective or the absorber area is minimized, and tend to improve as the character of the incident solar energy changes from collimated to diffuse. Based on these results, a hybrid MC/FV strategy is proposed for use in combined radiation and convection/conduction heat transfer models.

14/01134 Evaluation of optimal photovoltaic hybrid systems for remote villages in Far North Cameroon

Nfah, E. M. *Renewable Energy*, 2013, 51, 482–488.

Optimal photovoltaic (PV) hybrid systems (PVHS) have been evaluated for remote villages in the far north of Cameroon using a recent iterative optimization method based on desired annual number of generator hours and the net present value technique. PVHS configurations with the same PV array size were computed for varying energy demand (D1) and constant daily energy demand (D2) when the minimum desired renewable energy fraction was set to 20%. However, the annual diesel generator operating times in PVHS configurations were found to be higher for D1 at renewable energy fractions greater than 71.9%. The results of economic analysis using a PV module cost of a remote fuel price of €1.12/l, inflation rate of 5%, discount rate of 6%, 2 days' autonomy, PV module costs in the range €7.5–0.75/Wp, and fuel escalation rate in the range 5–20%, showed that PVHS were the optimal options for D2 for all combinations of sensitivity variables. PVHS were also found to be the optimal option for D1 at a fuel escalation rate of at most 10%. Standalone PV systems were found to be optimal option for D1 at a fuel escalation is at least 15% and PV module costs are in the range €2.25–0.75/Wp. The renewable energy fractions evaluated for optimal PVHS options were found to be in the ranges 88.7–97.0% and 89.4–99.9 % for D1 and D2, respectively. Consequently, PVHS are the optimal power option for the electrification of villages in the far north of Cameroon, with annual solar insolation of at least 5.5 kWh/m^2/day and annual energy demand of 72.6 kWh/day if the fuel escalation rate is at most 10%.

14/01135 Experimental investigation on photothermal properties of nanofluids for direct absorption solar thermal energy systems

He, Q. *et al. Energy Conversion and Management*, 2013, 73, 150–157.

In this study, Cu–H_2O nanofluids were prepared through two-step method. The transmittance of nanofluids over solar spectrum (250–2500 nm) was measured by the UV–Vis–NIR spectrophotometer based on integrating sphere principle. The factors influencing transmittance of nanofluids, such as particle size, mass fraction and optical path were investigated. The extinction coefficients measured experimentally were compared with the theoretical calculation value. Meanwhile, the photothermal properties of nanofluids were also investigated. The experimental results show that the transmittance of Cu–H_2O nanofluids is much less than that of deionized water, and decreases with increasing nanoparticle size, mass fraction and optical depth. The highest temperature of Cu–H_2O nanofluids (0.1 wt%) can increased up to 25.3% compared with deionized water. The good absorption ability of Cu–H_2O nanofluids for solar energy indicates that it is suitable for direct absorption solar thermal energy systems.

14/01136 Feasibility evaluation of solar photovoltaic pumping irrigation system based on analysis of dynamic variation of groundwater table

Gao, X. *et al. Applied Energy*, 2013, 105, 182–193.

Solar photovoltaic (PV) pumping irrigation system has become a widely applied solar energy technology over the past decades, in which the pump is driven by electricity produced by solar energy and lifts groundwater or surface water to irrigate the crop or grassland for agriculture. Qinghai Province, located in the Qinghai–Tibet Plateau, features abundant solar energy, but the problem of local grassland degradation and ecological deterioration has become increasingly serious. Using the clean solar energy to pump groundwater or surface water is of great significance for grassland recovery, environment protection and ecological restoration. In this study, the authors selected a demonstration site (with an area of 3.15 ha) in Tibetan Autonomous Prefecture of Golog at the southern part of Qinghai Province and evaluated the feasibility and performance of the PV pumping irrigation system at field scale. First, water demand of pasture was predicted in different hydrological level years to determine water deficiency, which should be replenished mainly by pumping groundwater according to the local water resources conditions. Second, through modelling the unsteady flow of partially penetrating well in unconfined aquifer, the authors analysed the change of groundwater table of the pumping well in both irrigation season and non-irrigation season, and then evaluated whether the groundwater resources can satisfy the pumping water demand for the growth of grassland. Results show that groundwater resources in the demonstration area are satisfactory and water yield in the pumping well can generally fulfil the water demand of grassland. Finally, based on balance analysis between solar energy supply and demand, a set of technical parameters were given to design the PV pumping irrigation system in the demonstration area. The authors also carried out a benefit analysis for the PV pumping irrigation system. It is concluded that, the PV system has good economic and ecological performance in the demonstration site compared to the diesel engine irrigation system, showing promising prospects to be popularized in western China at large scale.

14/01137 Heat transfer augmentation in a hybrid microchannel solar cell

Rahimi, M. *et al. International Communications in Heat and Mass Transfer*, 2013, 43, 131–137.

This paper considers experimental investigations on a hybrid microchannel solar cell, which is designed as an attractive technology for photovoltaic (PV) cooling systems. The proposed unit combines two elements: a microchannel and a photovoltaic–thermal module. Experiments were performed at indoor conditions. In order to remove heat from the PV module, water was used as a single-phase working fluid. Water flowed through series of microchannels with a hydraulic diameter of 0.667 mm. In the studied *Re* number range, detailed parametric investigation and energy evaluation were carried out for various fluid flow rates. The output power of the PV/T panel was compared with that of the conventional photovoltaic panel having no arrangement for heat removal. An excellent cooling performance was found from experiments so that the cell maximum power was marginally improved over 30%.

14/01138 Kinetics and heat transfer analysis of carbon catalyzed solar cracking process

Ozalp, N. *et al. Energy*, 2013, 55, 74–81.

Solar thermochemical processing offers production of many fuels and commodities via reduced emission footprint. Although solar reactor design and flow configuration play a key role in process efficiency, use of the right catalyst further enhances the overall efficiency. Solar cracking of methane provides an excellent example of the direct effect of carbon catalyst on the heat transfer which in turn affects the feedstock decomposition rate. In this paper, a compilation of the research results on the testing of carbon catalyst using thermogravimetry, and its impact on the heat transfer are summarized along with a thorough kinetics analysis of methane decomposition. It is seen that carbon seeding uniforms the reactor temperature and the volumetric heating caused by the suspended carbon particles substantially improves the reactor performance. Thirty-seven chemical gas-phase reactions and rate constants were considered to simulate the non-catalysed methane cracking, whereas eight chemical surface reactions and rate constants were considered for methane cracking with carbon catalyst. As for the heat transfer analysis, thermal interaction of gas-particle flow and the thermal hydraulics between gas flow and particle were studied by two way coupled Euler–Lagrange approach. Discrete ordinate model was used to solve radiative transport between reactor walls and entrained particles. The results show that when carbon loading is increased from 0.2 to 0.6 g/min, the product gas temperature reduces from 112 to 1010 K, whereas mass fractions of methane shows 30% increase in efficiency.

14/01139 Low-cost porous $Cu_2ZnSnSe_4$ film remarkably superior to noble Pt as counter electrode in quantum dot-sensitized solar cell system

Zeng, X. *et al. Journal of Power Sources*, 2013, 226, 359–362.

Lost-cost counter electrodes (CEs) based on $Cu_2ZnSnS(Se)4$ nanoparticles have been successfully introduced to quantum dot-sensitized solar cells (QDSCs). The investigation has demonstrated that the catalytic activity of $Cu_2ZnSnS(Se)_4$ based CEs is sensitive to the composition and thermal annealing condition. The $Cu_2ZnSnSe_4$ CE with porous structure, fabricated by spray deposition method and sintered at 450 °C in aqrgon atmosphere, exhibits an excel power conversion efficiency of 4.35% under AM 1.5 solar (100 mW cm^{-2}) irradiation in a QDSC, which is about 70% higher than that of device using the conventional thermally platinized conducting glass CEs.

14/01140 Photovoltaic performance degradation and recovery of the flexible dye-sensitized solar cells by bending and relaxing

He, X.-L. *et al. Journal of Power Sources*, 2013, 226, 173–178.

Flexibility, as well as high efficiency, of flexible dye-sensitized solar cells (DSCs) is of significant importance to their application. In this study, the photovoltaic performance of the flexible DSCs under bending and relaxed states is investigated to understand the degradation and recovery of the photovoltaic performance. Results show that when the bending radius is larger than 8 mm, the photovoltaic parameters of the flexible DSCs maintain the same values as those in the relaxed states. However, when the bending radius is reduced to 8 mm, the photovoltaic performance is two orders of magnitude decreased. Most interestingly, when the bending DSCs are relaxed, the photovoltaic performance is found to be completely recovered. The microstructure observation shows that the direct contact between TiO_2 film and counter electrode occurred at the bending radius of 8 mm, which should be the main reason for their low photovoltaic performance in the bending state. Finally, a modified equivalent circuit model is proposed for the flexible DSCs under bending condition.

14/01141 Photovoltaic remuneration policies in the European Union

Sarasa-Maestro, C. J. *et al. Energy Policy*, 2013, 55, 317–328.

The purpose of this paper is to study the development of photovoltaic (PV) systems in some countries of the European Union (EU). The authors establish the stage of development of each country, their short- and long-term degree of compliance and the trends of international investors favouring one market or another. EU countries employ four major types of programs to encourage PV use: (1) feed-in tariffs (FIT), (2) green certificates with a quota system, (3) investment and tax incentives, and (4) bids on the quota system. The FIT is the most widely used programme to create incentives for the use of PV systems. During the past 2 years, PV tariffs have been reduced in many European countries. Investments in PV are still attractive, in some cases even overly generous with respect to the financial landscape in the world. This paper shows, for each country, the type of incentive and the trends in and forecast for installed capacity and calculates the internal rate of return for investment in grid-connected PV systems.

14/01142 Renewables in the energy transition: evidence on solar home systems and lighting fuel choice in Kenya

Lay, J. *et al. Energy Economics*, 2013, 40, 350–359.

This study considers the determinants of households' choices of lighting fuels in Kenya including the option of using solar home systems (SHS). The goal is to add new evidence on the factors that influence the introduction and adoption of decentralized and less carbon-intensive energy sources in developing countries, and, more generally, to the empirical debate on the energy ladder. This study capitalizes on a unique representative survey on energy use and sources from Kenya, one of the few relatively well-established SHS markets in the world. The results reveal some very interesting patterns of the fuel transition in the context of lighting fuel choices. While clear evidence was found for a cross-sectional energy ladder, the income threshold for modern fuel use – including solar energy use – to move beyond traditional and transitional fuels is very high. Income and education turn out to be key determinants of SHS adoption, but a very pronounced effect of SHS clustering was also found, i.e. the prevalence of SHS in the proximity of a potential user increases the likelihood of adoption. In addition, a negative correlation was found between grid access and SHS use.

14/01143 Sizing of a standalone photovoltaic/battery system at minimum cost for remote housing electrification in Sohar, Oman

Kazem, H. A. *et al. Energy and Buildings*, 2013, 61, 108–115.

This paper presents a method for optimal sizing of a standalone PV system for remote areas in Sohar, Oman. PV array tilt angle as well as the size of the system's energy sources are designed optimally for better performance and lower energy cost. Numerical methods for optimization of the PV module tilt angle, PV array size and storage battery capacity are implemented using MATLAB and hourly meteorological data and load demand. The results show that for Sohar zone the tilt angle of a PV array must be adjusted twice a year. The PV array must be slanted at 49° in the period of 21/09–21/03 ($n = 255–81$), while it must be horizontal (tilt angle is zero) in the period of 21/03–21/09 ($n = 81–255$). This adjustment practice gains the energy collected by a PV array by 20.6%. As for the PV system size, the results show that the sizing ration of the PV array for Oman is 1.33 while the sizing ratio for battery is 1.6. However the cost of the energy generated by the proposed system is US$0.196/kWh.

14/01144 Solar radiation manipulations and their role in greenhouse claddings: Fresnel lenses, NIR- and UV-blocking materials

Lamnatou, C. and Chemisana, D. *Renewable and Sustainable Energy Reviews*, 2013, 18, 271–287.

From the global solar radiation which enters the greenhouse interior space only photosynthetic active radiation (PAR) is absorbed by the plants and is important for their growth and photosynthesis. Thereby, sunlight spectral modifications which affect the quality and quantity of the incoming solar radiation are valuable and can be achieved by using specific kinds of cladding materials. In this study, some critical kinds of greenhouse claddings which are related with sunlight modifications are reviewed. The claddings considered include: Fresnel lenses, near-infrared (NIR)- and ultraviolet (UV)-blocking materials. The authors refer to some representative studies from the literature and make critical comments on each cladding category based on factors such as the feasibility for practical applications. Regarding the presented types of greenhouse covers, they have the potential for further development in a cost-effective way. Cost-effective solar energy technologies, for example Fresnel lenses combined with simple concentrating thermal systems can provide advantages such as temperature/light control of greenhouse interior space along with production of thermal energy for greenhouse energy needs.

14/01145 Solar water heating systems and their market trends

Islam, M. R. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 1–25.

This review paper primarily discusses the design features and related technical advancements of the solar water heating (SWH) systems in terms of energy efficiency and cost-effectiveness. One of the widely acknowledged benefits of the SWH systems is in the potential of energy savings. Therefore, the economic evaluation and the life cycle analysis are a necessary assessment to determine the feasibility of such systems. All of the economic evaluation factors that affect the SWH systems are also discussed in this review to find the specific energy efficient approaches depending on the size and particular energy demands. Using all of the discussed factors of this review, the actual penetration of the SWH systems in any demographic area can be assessed. This accurate economic potential assessment is necessary to increase the number of SWH consumers. Although few countries/places are more concerned in promoting SWH systems by overcoming all of the technical and economic barriers, it is not been equally promoted in the rest of the world because of several economical and technical issues. In this study it was observed that the installation of SWH systems are more feasible on a large area compared to small unit-wise installation per households in terms of energy conservation and per unit energy cost over initial costs. In many large-scale applications, such as commercial building sectors, both economic and technological feasibility assessment can contribute in the reduction of energy cost. In the case of packaged SWH units, currently many small enterprises are in the manufacturing stages worldwide. However, the cost and quality of the products are still not in the satisfactory level. More government rebates and benefits could help the small-scale manufacturers to flourish more by maintaining quality assurance. Moreover, to ensure the quality of the SWH systems from large to small-scale, stricter quality control rules should be imposed, so that it can compete with the conventional water heating systems. The entry status of the SWH products in the market with respect to the product quality and supply is also a major requirement for the promotion of such SWH technologies. Environmental preferences and reliability are two competitive benefits of SWH systems in the international market. Finally, it can be said that the use of SWH systems can have a great impact on the economic, environmental, and energy conservation perspectives.

14/01146 Sorption thermal storage for solar energy

Yu, N. *et al. Progress in Energy and Combustion Science*, 2013, 39, (5), 489–514.

Sorption technologies, which are considered mainly for solar cooling and heat pumping before, have gained a lot of interests for heat storage of solar energy in recent years, due to their high energy densities and long-term preservation ability for thermal energy. The aim of this review is to provide an insight into the basic knowledge and the current state of the art of research on sorption thermal storage technologies. The first section is concerned with the terminology and classification for sorption processes to give a clear scope of discussion in this paper. Sorption thermal storage is suggested to cover four technologies: liquid absorption, solid adsorption, chemical reaction and composite materials. Then the storage mechanisms and descriptions of basic closed and open cycles are given. The progress of sorption materials, cycles, and systems are also reviewed. Besides the well-known sorbents like silica gels and zeolites, some new materials, including aluminophosphates, silico-aluminophosphates and metal-organic frameworks, are proposed for heat storage. As energy density is a key criterion, emphasis is given to the comparison of storage densities and charging temperatures for different materials. Ongoing research and development studies show that the challenges of the technology focus on the aspects of different types of sorption materials, the configurations of absorption cycles and advanced adsorption reactors. Booming progress illustrates that sorption thermal storage is a realistic and sustainable option for storing solar energy, especially for long-term applications. To bring the sorption storage solution into market, more intensive studies in fields of evaluation of advanced materials and development of efficient and compact prototypes are still required.

14/01147 Systems and control challenges in photovoltaic manufacturing processes: a modeling strategy for passivation and antireflection films

Adomaitis, R. A. and Schwarm, A. *Computers & Chemical Engineering*, 2013, 51, 65–76.

A view of contemporary systems and control challenges in photovoltaic cell manufacturing is given in this paper, with emphasis on developing a modelling strategy for the optimization of silicon nitride $SiN_x:H$ films used for passivation and antireflection coatings in single and multi-crystalline silicon solar cells. The overall framework integrates three modelling modules: a remote plasma-enhanced chemical vapour deposition reactor process model that predicts film composition and thickness based on process input parameters, a solar-optical module that relates antireflection film physical and chemical properties to the degree to which the spectral irradiance distribution is attenuated, and a solar cell device model that predicts cell power output and efficiency from the film properties and irradiance. Because the model couples process inputs to both photovoltaic cell performance and manufacturing process efficiency, the modelling approach can be used for the simultaneous optimization of process and product performance.

14/01148 Tailor and functionalize TiO_2 compact layer by acid treatment for high performance dye-sensitized solar cell and its enhancement mechanism

Guai, G. H. *et al. Renewable Energy*, 2013, 51, 29–35.

Surface tailoring and functionalization of an annealed TiO_2 compact layer by H_2SO_4 acid was performed to improve the dye-sensitized solar cell (DSSC) performance. Compared to untreated counterpart, the acid-treated compact layer possesses a rougher surface and more hydroxyl groups, which result in increased surface area and enhanced adherence of the compact layer with the mesoporous TiO_2 film by Ti–O–Ti bonds formed by a followed heating process. Impedance measurement was further used to investigate the enhancement mechanism, indicating the acid post treatment of the TiO_2 compact layer reduces the ohmic bulk resistivity while effectively suppressing charge recombination at FTO/electrolyte interface. In DSSCs with untreated TiO_2 compact layer, a significantly increased series resistivity is very likely to be the rate determining factor to limit the charge separation process. Thus, an optimal post acid treatment could reduce the resistivity for high charge transport, resulting in larger short-circuit current for further improvement of power conversion efficiency from 6.60% in DSSC with untreated compact layer to 7.21% in DSSC with acid-treated compact layer. This work also provides fundamental insight of the compact layer for DSSC performance improvement.

14/01149 Techno-economic analysis of solar parabolic trough type energy system for garment zone of Jaipur city

Mathur, A. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 104–109.

Energy crisis and environmental problems require a new sustainable energy supply option that uses renewable energies and is economic at the same time. Solar thermal power (STP) generating systems are proven renewable energy technologies and often a very cost effective way to produce electricity from solar radiation. In this paper, the potential and the cost-effectiveness of a parabolic trough collector (PTC) type solar thermal power plant for meeting the energy demand of garment-manufacturing zone at Sitapura industrial area, Jaipur, India, is analysed. In this, the present energy demand of garment zone, design of proposed solar power plant and economic evaluation of the power plant has been carried out. The estimated energy requirement of the selected garment zone was 2.21 MW for year 2011. To meet the present energy demand and expected increase in the demand a PTC-type solar power plant of 2.5 MW capacity is proposed, which require about 15.76 acres of land area and has 256 solar collector elements. Looking to the scarcity and cost of the land near the city, off-site proposal of the power plant has also been considered and compared with on-site option. Four economic scenarios were analysed for the proposed system and their financial performance is evaluated. For the onsite solar power plant internal rate of return is 19.21%, NPV at 10% discount rate is INR372.77 million, simple payback period is 5 years and discounted payback period @10% is 7 years and 4 months, while for the off-site power plant internal rate of return is 27.85%, NPV is INR550.55 million, simple payback period is 3 years and 6 months and discounted payback period is 4 years and 7 months. Levelized cost of energy for onsite power plant is INR9.41/kWh and for offsite power plant is INR6.89/kWh.

14/01150 The best time to invest in photovoltaic panels in Flanders

Beliën, J. *et al. Renewable Energy*, 2013, 50, 348–358.

Up to now, there has been some controversy about green certificates (a form of subsidy) that are granted for the installation of photovoltaic (PV) panels in the Flemish residential sector. The Flemish government has already reduced the value of future green certificates, because they appeared to be excessively high. Currently, power providers have to pay for these certificates. Owners not having a PV installation suspect that they will be charged for those additional costs in the form of rising energy bills. As such, it seems that investing in PV panels would end up being the cheapest option for them in the long run. At the same time, the following trends were observed in analysing costs and benefits in installing PV panels in the Flemish residential sector: the PV industry is booming causing PV panels to become cheaper; energy prices will continue to rise (with or without including the recovery of green certificates costs); tax revenues on the investment cost will be abolished; and the value of green certificates decreases when households postpone their investment in PV panels. It is therefore worth investigating when the investment in PV panels for the Flemish residential sector is optimal in terms of time. The authors compared the timing of different investments by analysing their future value and return, embedded in a sensitivity analysis. By forecasting all relevant parameters, the analysis points out that the best period for investing in PV panels for the Flemish residential sector was December 2010 or June 2011. After 2011, PV panels remain a responsible financial investment but with a lower rate of return. The results further indicate that investment in PV panels was and still remains over-subsidized: the energy cost savings alone are almost sufficient to cover the investment cost. Therefore, the government should continue to decrease the subsidies in the near future. Apart from saving money, this would also stimulate the average Flemish household to invest in PV panels as soon as possible.

14/01151 The potential contribution of solar thermal collection and storage systems to meeting the energy requirements of north European housing

Ampatzi, E. *et al. Solar Energy*, 2013, 91, 402–421.

The focus of this work is on the proportion of the overall energy currently consumed for thermal comfort and hot water preparation that could be supplied by solar energy harvested by active, water-based, systems including heat storage in houses in northern Europe. Twelve typical dwellings drawn from a recent survey and considered as representative of 50% of the Welsh housing stock are modelled and the solar collectors' yield for different orientations and tilts is predicted. A range of absorber orientations and storage capacities are analysed in relation to the resulting solar contribution. It is revealed that solar energy has a role to play in reducing the amount of conventional energy currently consumed for heating and domestic hot water preparation in existing dwellings in this region. Up to 34% solar contribution could be possible by instantaneous use of the absorbed energy, if the energy demand and availability are well matched. It is also shown that uncommonly large collector areas could significantly increase the solar usability in existing houses in this region, resulting in around 50% solar contribution with small store sizes. Large storage capacities would marginally increase the delivered solar heat, but only in some cases where unrealistically large collector areas are used.

14/01152 The potential for air-temperature impact from large-scale deployment of solar photovoltaic arrays in urban areas

Taha, H. *Solar Energy*, 2013, 91, 358–367.

Among the many benefits of solar photovoltaic (PV) systems, the direct effects are those of providing local power and the indirect ones include avoided generation from fossil-fuel power plants. The latter translate into reduced emissions of greenhouse gas (thus reduced radiative forcing) and other pollutants, such as ozone precursors (thus improved air quality). Because large-scale PV deployments can alter the radiative balance at the surface-atmosphere interface, they can exert certain impacts on the temperature and flow fields. In this analysis, meteorological modelling was performed for the Los Angeles region as a case study to evaluate the potential atmospheric effects of solar PV deployment. The simulations show no adverse impacts on air temperature and urban heat islands from large-scale PV deployment. For the range of solar conversion efficiencies currently available or expected to become attainable in the near future, the deployment of solar PV can cool the urban environment. The cooling can reach up to 0.2 C in the Los Angeles region. Under hypothetical future-year scenarios of cool cities (urban areas with extensive implementations of highly-reflective roofs and pavements) and high-density deployments of urban solar PV arrays, some adverse impacts (0.1 C or less in warming) might occur. However, such extreme high-density deployments of cool surfaces are not expected and thus the warming effects are unlikely to result.

14/01153 The prospects for cost competitive solar PV power

Reichelstein, S. and Yorston, M. *Energy Policy*, 2013, 55, 117–127.

New solar photovoltaic (PV) installations have grown globally at a rapid pace in recent years. The authors provide a comprehensive assessment of the cost competitiveness of this electric power source. Based on data available for the second half of 2011, the authors conclude that utility-scale PV installations are not yet cost competitive with fossil fuel power plants. In contrast, commercial-scale installations have already attained cost parity in the sense that the generating cost of power from solar PV is comparable to the retail electricity prices that commercial users pay, at least in certain parts of the USA. This conclusion is shown to depend crucially on both the current federal tax subsidies for solar power and an ideal geographic location for the solar installation. Projecting recent industry trends into the future, the authors estimate that utility-scale solar PV facilities are on track to become cost competitive by the end of this decade. Furthermore, commercial-scale installations could reach 'grid parity' in about ten years, if the current federal tax incentives for solar power were to expire at that point.

14/01154 Thermal characterization of nitrates and nitrates/expanded graphite mixture phase change materials for solar energy storage

Xiao, X. *et al. Energy Conversion and Management*, 2013, 73, 86–94.
Solar energy storage has become more attractive in recent years. In particular, latent thermal energy storage (LTES) with large energy storage density and isothermal heat storage/retrieval characteristics is a hot research topic. In the present study, sodium nitrate, potassium nitrate and their mixture were used as the base materials, and expanded graphite (EG) with high thermal conductivity and thermochemical stability was used as an additive to enhance the thermal conductivity. EG with various mass fractions was added to the base materials to form mixture phase change materials (PCMs), and the thermal characteristics of the mixtures were studied extensively. The transient hot-wire tests showed that the addition of EG enhanced the apparent thermal conductivity significantly, e.g. the apparent thermal conductivity of the nitrates/10 wt% EG mixture PCM was increased by about 30–40%. The test results showed good agreement with theoretical calculations of the quadratic parallel model. Tests with differential scanning calorimeter revealed that the melting/freezing temperatures of the mixture PCMs shifted slightly, compared with those of pure nitrates.

14/01155 Thermal efficiency of solar collector made from thermoplastics

Ariyawiriyanan, W. *et al. Energy Procedia*, 2013, 34, 500–505.
Thermoplastics solar collectors have been used to replace typical metal collectors because they are less expensive, lighter in weight and more integrated. The effect of thermal conductivity and collector area was observed for four type of themoplastics: polyvinyl chloride-blue), polybutene, polypropylene random copolymer and polyvinyl chloride–carbon black. A collector area of 2 m^2 was prepared as for solar collectors. The position of collector panel was set to south orientation and at 14° to the horizontal, which is the collector slope to obtain the highest annual efficiency in Thailand. A data logger collected data from 9.00–16.00 throughout the day according to ASHRAE 93–77. The mass flow rate of water in collector was 0.02 $kg\,s^{-1}$. The results of the differing thermal conductivity materials indicate that the materials make no difference to collector thermal efficiency. The collector efficiency depends on the area of the panel. Therefore, this implies that the future design of plastic solar collectors should consider both thermal conductivity and absorbed area. Polyvinyl chloride–carbon black was suggested as a suitable plastic solar collector.

14/01156 Thermal performance analysis of a line-focus Fresnel lens solar collector using different cavity receivers

Xie, W. T. *et al. Solar Energy*, 2013, 91, 242–255.
In this paper, a line-focus Fresnel lens solar collector using different cavity receivers are studied and compared. Thermal performance of the line-focus Fresnel lens solar collector with each cavity receiver is studied experimentally at different temperature levels. The efficiency factors and heat removal factors of Fresnel lens solar collectors using different kinds of line-focus cavity receivers are obtained both theoretically and experimentally. Eight kinds of cavity receivers, namely: triangular, arc-shaped, rectangular, semicircular, positive trapezoidal, reverse trapezoidal, hetero trapezoidal and convex, are tested and analysed. It is found that the theoretical results agree well with the test results. For the line-focus Fresnel lens solar collector, the triangular cavity receiver shows the best thermal performance. The highest experimental heat removal factor is about 0.805 when the operation temperature is 180 °C. Results show that under given operation conditions, the optimum width of cavity aperture, the optimum inside diameter of the receiver tube and the optimum vertex angle of the cross section of the receiver are 50 mm, 18 mm and 60°, respectively. It is recommended that the geometrical concentration ratio of the studied Fresnel lens solar collector should be more than 55. The experimental heat removal factors for triangular cavity receivers are increased to 0.879 (using rectangular pipelines as the absorber plate) and 0.873 (using tube bundles as the absorber plate) respectively, after optimization.

Wind energy

14/01157 A group-based spatial decision support system for wind farm site selection in northwest Ohio

Gorsevski, P. V. *et al. Energy Policy*, 2013, 55, 374–385.
The purpose of this paper is to demonstrate the benefits of applying a spatial decision support system (SDSS) framework for evaluating the suitability for wind farm siting in north-west Ohio. The multiple criteria evaluation (MCE) prototype system is intended for regional planning but also for promoting group decision making that could involve participants with different interests in the development of decision alternatives. The framework integrates environmental and economic criteria and builds a hierarchy for wind farm siting using weighted linear combination (WLC) techniques and geographic information system functionality. The SDSS allows the multiple participants to interact and develop an understanding of the spatial data for assigning importance values to each factor. The WLC technique is used to combine the assigned values with map layers, which are standardized using fuzzy set theory, to produce individual suitability maps. The maps created by personal preferences from the participants are aggregated for producing a group solution using the Borda method. Sensitivity analysis is performed on the group solution to examine how small changes in the factor weights affect the calculated suitability scores. The results from the sensitivity analysis are intended to aid understanding of compromised solutions through changes in the input data from the participant's perspective.

14/01158 Discrete sliding mode control strategy for direct real and reactive power regulation of wind driven DFIG

Pande, V. N. *et al. Electric Power Systems Research*, 2013, 100, 73–81.
This paper investigates a discrete sliding mode control (DSMC) strategy for direct real and reactive power regulation for wind driven doubly fed induction generator (DFIG). The real and reactive power errors are eliminated by directly calculating the rotor control voltages through DSMC. In the stator stationary reference frame, direct real and reactive power control strategy is implemented. Therefore, it does not require the angular information of the stator and rotor currents or voltages. It does not involve any extra current loops which results into simple design. The use of constant converter switching frequency via space vector pulse width modulation eases the AC harmonic filter design and improves the power quality. The use of fast and flexible discrete controller makes the system competent with modern digital world. Detailed simulations have been carried out to validate the method. The simulation results reveal that the real and reactive power references are followed smoothly even in the presence of speed perturbations and performance of the system is robust against parameter variations and system disturbances.

14/01159 Factors influencing the technology upgrading and catch-up of Chinese wind turbine manufacturers: technology acquisition mechanisms and government policies

Qiu, Y. *et al. Energy Policy*, 2013, 55, 305–318.
This paper uses firm-level data for the Chinese wind turbine manufacturing industry from 1998 to 2009 to quantify the effects of technology acquisition mechanisms – purchasing production licenses from foreign manufacturers, joint design with foreign design firms, joint-ventures and domestic R&D – on wind turbine manufacturers' technology levels (as measured by turbine size, in megawatts). It also examines the impacts of government policies on manufacturer technology levels. Technology upgrading (measured by increase of turbine size) and catch-up (measured by decrease in the distance to the world technology frontier in terms of turbine size) are used to measure advances in technology level. Results from econometric modelling studies indicate that firms' technology acquisition mechanisms and degree of business diversification are statistically significant factors in influencing technology upgrading. Similar results were found for the catch-up variable (i.e. distance to the world technology frontier). The influence of government policies is significant for technology upgrading but not catch-up. These and other modelling results are shown to have implications for both policymakers and wind turbine manufacturers.

14/01160 Maximum power extraction from wind energy system based on fuzzy logic control

Eltamaly, A. M. and Farh, H. M. *Electric Power Systems Research*, 2013, 97, 144–150.
This paper proposes a variable speed control scheme for grid-connected wind energy conversion system (WECS) using permanent magnet synchronous generator (PMSG). The control algorithm tracks the maximum power for wind speeds below rated speed of wind turbines and ensures the power will not go over the rated power for wind speeds over the rated value. The control algorithm employs fuzzy logic controller (FLC) to effectively do this target. The wind turbine is connected to the grid via back-to-back PWM-VSC. Two effective computer simulation packages (PSIM and Simulink) are used to carry out the simulation effectively. The control system has two controllers for generator-side and grid-side converters. The main function of the generator-side controller is to track the maximum power through controlling the rotational speed of the wind turbine using FLC. In the grid-side converter, active and reactive power control has been achieved by controlling *q*-axis and *d*-axis current components, respectively. The *d*-axis current is set at zero for unity power factor and the *q*-axis current is controlled to deliver the power flowing from the dc-link to the electric utility grid.

14/01161 Modeling of financial incentives for investments in energy storage systems that promote the large-scale integration of wind energy

Zafirakis, D. *et al. Applied Energy*, 2013, 105, 138–154.

The recent literature on applied energy has emphasized the role of energy storage in the electricity supply chain. However, absence of an integrated valuation framework for services provided by energy storage technologies, owed to its limited scope so far, hinders investments in such capital-intensive systems. To this end, the feasibility of an alternative operation strategy for energy storage systems (ESSs), based on the use of wind energy surplus, was investigated. More precisely, a valuation of the policy options available to promote wind-based ESSs was carried out, by employing, for the first time, a comprehensive socioeconomic cost-benefit model that takes into account, among others, initial investment subsidies and feed-in tariffs (FiTs) for ESSs. Pumped hydro and compressed air energy storage covering peak demand were examined, demonstrating that such systems may prove cost-effective if ‘socially just’ FiTs are applied, with the findings, also supporting the notion that a portfolio of policies can more effectively facilitate investments in the sector.

14/01162 Optimal operation scheduling of wind power integrated with compressed air energy storage (CAES)

Abbaspour, M. *et al. Renewable Energy*, 2013, 51, 53–59.

This study optimizes and compares the operation of a conventional gas-fired power generation company with its operation in combination with wind power and compressed air energy storage (CAES). A mixed integer non-linear programming formulation is developed for the optimization problem. Limits in ramp rate, capacity, and minimum on/off time, as well as start-up cost constraints, are considered for the modelling of conventional units. Injected and produced power constraints, storage, air balance and CAES-operation limits are considered in the CAES modelling. Two objective functions (profit maximization and cost minimization) are modelled. Without considering capital costs, it is found that the use of CAES results in 43% higher operational profits and 6.7% lower costs in a market environment.

14/01163 Optimal tracking and robust power control of the DFIG wind turbine

Abdeddaim, A. and Betka, A. *International Journal of Electric Power & Energy Systems*, 2013, 49, 234–242.

In the present paper, an optimal operation of a grid-connected variable speed wind turbine equipped with a doubly-fed induction generator (DFIG) is presented. The proposed cascaded non-linear controller is designed to perform two main objectives. In the outer loop, a maximum power point tracking (MPPT) algorithm based on fuzzy logic theory is designed to permanently extract the optimal aerodynamic energy, whereas in the inner loop, a second order sliding mode control (2-SM) is applied to achieve smooth regulation of both stator active and reactive powers quantities. The obtained simulation results show a permanent track of the MPP point regardless of the turbine power-speed slope moreover the proposed sliding mode control strategy presents attractive features such as chattering-free, compared to the conventional first order sliding technique.

14/01164 Post-evaluation indicator framework for wind farm planning in China

Wu, Y. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 26–34.

Compared with traditional fossil fuel energy, wind power is becoming more and more popular relies on its environment protected characteristic. In China, the wind power industry has undergone a rapid development based on the rapid development of wind power technology and the support from Chinese government policy. However, there is still a big difference between actual generating capacity and design data, which has caused a great impact on people’s life and running of power grid. It is necessary to have a post-evaluation on wind farm planning. Based on studying domestic and foreign literatures that are about evaluation on wind farms, this paper gets a more comprehensive and integrated post-evaluation dedicator framework on wind farm planning. This framework consists of four indicators and 10 sub-indicators, and also adds in evaluation study on management effect particularly, proposes a new evaluation perspective compared with the existing research.

14/01165 Site specific optimization of wind turbines energy cost: iterative approach

Mirghaed, M. R. and Roshandel, R. *Energy Conversion and Management*, 2013, 73, 167–175.

The present study was aimed at developing a model to optimize the sizing parameters and farm layout of wind turbines according to the wind resource and economic aspects. The proposed model, including aerodynamic, economic and optimization sub-models, is used to achieve minimum levelized cost of electricity. The blade element momentum theory is utilized for aerodynamic modelling of pitch-regulated horizontal axis wind turbines. Also, a comprehensive cost model including capital costs of all turbine components is considered. An iterative approach is used to develop the optimization model. The modelling results are presented for three potential regions in Iran: Khaf, Ahar and Manjil. The optimum configurations and sizing for a single turbine with minimum levelized cost of electricity are presented. The optimal cost of energy for one turbine is calculated about $46.7, $54.5 and $46.6 per MW h in the studied sites, respectively. In addition, optimal size of turbines, annual electricity production, capital cost, and wind farm layout for two different rectangular and square shaped farms in the proposed areas have been recognized. According to the results, optimal system configuration corresponds to minimum levelized cost of electricity from about $45.8 to $67.2 per MW h in the studied wind farms.

14/01166 Study on increasing wind power in buildings using TRIZ tool in urban areas

Padmanabhan, K. K. *Energy and Buildings*, 2013, 61, 344–348.

The velocity of wind in an urban location is comparatively lower than in rural or semirural locations. This paper deals with the study of a new methodology to increase the wind speed and power output of small turbines located in urban areas. The new methodology is adopted based on TRIZ (theory of solving inventive problems) principles. This idea was obtained from the different shapes adopted for the roof tops of buildings at various locations. The methodology used here studies the impact of monoslide roof shape on wind speed using computational fluid dynamics (CFD). Majority of buildings in India have flat roofs. So, the paper suggests the use of adjustable roof so that the roofs could be tilted at various angles. The present study gives a diagrammatical representation of the new method and an analysis using CFD. Measuring the velocity of wind at an urban location at various altitudes and at various locations of the buildings is a complex task. CFD is already a necessary tool for modelling the wind over complex urban terrains. This study underlines a system to reduce the passiveness and idle time of wind turbines located in buildings. That could make the urban wind turbine more agile and active for higher power generation and resource utilization.

14/01167 Theoretical analysis of an airborne wind energy conversion system with a ground generator and fast motion transfer

Goldstein, L. *Energy*, 2013, 55, 987–995.

A novel airborne wind energy conversion concept is presented, in which the wind power, which is harvested by the crosswind motion of a tethered wing, is transferred to a ground-based generator by a belt with a high speed close to the speed of the wing. The belt trails behind the wing. The high speed of the motion transferring belt results in a low belt tension, a high rotational speed and a low torque on the shaft connected to the rotor. The theoretical analysis and numeric calculations, which consider the drag of the tether and the weight of both the tether and the wing, demonstrate the practical feasibility of the concept. Two practical constructions are described, one with a single wing and one with two wings in counter phase. The economic analysis shows that the proposed system is 10 times less expensive than a conventional wind turbine with a comparable average power output.

14/01168 Where the wind blows: assessing the effect of fixed and premium based feed-in tariffs on the spatial diversification of wind turbines

Schmidt, J. *et al. Energy Economics*, 2013, 40, 269–276.

Feed-in tariffs (FIT) are among the most important policy instruments to promote renewable electricity production. The fixed-price FIT (FFIT), which guarantee a fixed price for every unit of produced electricity and the premium based FIT (PFIT), which pay a premium on top of the market price are commonly implemented in the European Union. Costs for balancing intermittent electricity production may be significantly higher with FFIT than with PFIT, and FFIT do not provide any incentive to produce electricity when marginal production costs are high. In contrast, PFIT do provide strong incentives to better match renewable power output with marginal production costs in the system. The purpose of this article is to assess the effects of the two tariff schemes on the choice of wind turbine locations. In an analytical model, the authors show that both the covariance between wind power supply and demand as well as between the different wind power locations matter for investors in a PFIT scheme. High covariance with other intermittent producers causes a decrease in market prices and consequently in revenues for wind power investors. They are therefore incentivized to diversify the locations of wind turbines to decrease the covariance between different wind power production locations. In an empirical optimization model, the authors analyse the effects of these two different schemes in a policy experiment for Austria. The numerical results show that under a PFIT scheme, (1) spatial diversification is incentivized, (2) the covariance of wind power production with marginal electricity production costs increases, and (3) the variances of the wind power output and of residual load decrease if wind power deployment attains 10% of total national electricity consumption.

Others, including economics

14/01169 A comprehensive analysis of strategies, policies and development of hydropower in India: special emphasis on small hydro power

Sharma, N. K. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 460–470.

Many developing countries like India are facing energy crisis due to increase in industrialization for various development programmes. If this increase in demand is supplied from coal based thermal power plants, it will cause environment pollution and high cost of generation. So the best solution is to develop hydropower and small hydropower (SHP) plants in the country. India is endowed with these resources which are both viable and economically exploitable. In fact, hydro power is the second highest contributor of the energy consumed in the Indian power sector. At the present time, it is the only clean energy source that can be commercially developed on a large as well as small scale. Recently, hydropower and SHP have considered as most readily available, renewable and clean sources of electricity. They use the potential energy of rivers and supply more than 20% of total India's electricity. Also, SHP has some advantages: it may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, SHP projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network so as to improve the quality of life. Therefore, this paper has been focused on the efforts to analyse the current status, future strategies and policies of hydropower development in India with special emphasis on SHP.

14/01170 A nation-wide planning of agro-residue utility for bioethanol production and power generation in Ecuador

Garcia M., J. C. *et al. Energy Procedia*, 2013, 34, 57–63.

This paper presents a nationwide planning of agro-residue utility for bioethanol production and power generation in Ecuador. The study is based on a previous work of optimization of plant allocation for bioethanol production from lignocellulosic feedstock. Here, the aim is to conduct a CO_2 and energy assessment, and two scenarios were set to produce the necessary supply of E15 and bio-electricity to be replaced in the country by optimizing feedstock selection and energy provision from plants to provinces. The first experiment is performed under no-restriction and is to maximize total CO_2 reduction. The second experiment is described as to enlarge CO_2 reduction as one of the restrictions but also to maximize energy supply according to energy sufficiency levels. The results conclude that selecting high efficiency and easy-to-derive feedstock and matching demand and supply distribution are the key measures in planning nation-wide biomass energy utility.

14/01171 A review of energy storage technologies for marine current energy systems

Zhou, Z. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 390–400.

Increasing concerns about the depletion of fossil resources and the issue of environment lead to a global need for producing more clean energy from renewable sources. Ocean is appreciated as a vast source of renewable energies. Considering marine renewable energies, it can be noticed that significant electrical power can be extracted from marine tidal currents. However, the power harnessed from marine tidal currents is highly fluctuant due to the swell effect and the periodicity of the tidal phenomenon. To improve the power quality and make the marine generation system more reliable, energy storage systems can play a crucial role. In this paper, an overview and the state of art of energy storage technologies are presented. Characteristics of various energy storage technologies are analysed and compared for this particular application. The comparison shows that high-energy batteries like sodium–sulfur battery and flow battery are favourable for smoothing the long-period power fluctuation due to the tide phenomenon while supercapacitor and flywheel are more suitable for eliminating short-period power disturbances due to swell or turbulence phenomena. This means that hybrid storage technologies are needed for achieving optimal results in tidal marine current energy applications.

14/01172 An economic and functional tool for assessing the financial feasibility of farm-based anaerobic digesters

Anderson, R. C. *et al. Renewable Energy*, 2013, 51, 85–92.

Anaerobic digester (AD) technology is a form of renewable energy with significant upside potential and little public resistance. However, previous studies have generally found ADs to be a poor investment for private firms without public assistance. The mixed results on the financial feasibility of ADs could be due to the site of the analysis since results vary with size, geographic location or the type of AD system, which are not standardized but rather customized to the individual situation. Given the public and private interest in AD technology and the need to assess the feasibility by site, a decision-making tool that can be adapted for each location and system would aid assessing the investment. This paper presents a freely available workbook to determine the financial feasibility of a farm-based AD and to demonstrate its use. The decision-making tool identifies the technical and financial parameters affecting the returns to an AD and the sensitivity of the assumption to changes in the value of those parameters. An application of the workbook for the Ontario livestock sector demonstrates its usefulness. Investment in an AD is financially feasible only for the largest dairy farms in Ontario under current electricity prices, which are approximately six times greater than the wholesale price. Shifting to a duel fuel continuous system would improve returns, as would the availability of additional substrate material in the form of solid grease and vegetative waste. Reductions in capital cost and improvements in the efficiency of the technology are probable given the relatively infant status of the biogas sector but these future enhancements would likely only alter the investment decisions for large commercial dairy farms.

14/01173 An experimental study of a floating breakwater with asymmetric pneumatic chambers for wave energy extraction

He, F. *et al. Applied Energy*, 2013, 106, 222–231.

Integrating oscillating-water-column type converters (pneumatic chambers) with slack-moored floating breakwaters can be a viable option for cost-sharing between wave energy capturing devices and shore-protection structures, and thus enhance the cost-effectiveness of wave energy utilization. When designing such integrated systems, it is desirable to have a system that can capture wave energy over a wide range of wave frequency. In this study, a configuration of floating breakwater with asymmetric pneumatic chambers (a narrower chamber on the seaside and a wider chamber on the leeside) is proposed to increase the amplitude of the oscillating air-pressures inside both chambers over a wide range of wave frequency (thus to improve the performance in wave energy extraction). A series of experiments were carried out under regular wave conditions to study the effects of asymmetric pneumatic chambers on the hydrodynamic performance of the floating breakwater and on the oscillating air-pressures inside the two chambers. It was shown that (1) the breakwater with asymmetric chambers performed as good as that with symmetric chambers in terms of wave transmission and motion responses and (2) with asymmetric configuration, it is possible to increase the amplitude of the oscillating air-pressures inside both chambers. The new concept provides a promising way to extend the frequency range over which wave energy can be extracted.

14/01174 An optimization model for renewable energy generation and its application in China: a perspective of maximum utilization

Cong, R.-G. *Renewable and Sustainable Energy Reviews*, 2013, 17, 94–103.

In response to climate change, China's power industry is undertaking the task of reducing carbon emissions. Renewable energy generation has become an important option. For the government and state grid companies, it is important to know the maximum possible capacities of renewable energy generation from its different sources in order to plan the construction of the power grid in the future. In this paper, several important factors affecting the development of renewable energy generation are identified through a review of the existing literature (such as cost, technical maturity and so on) and analysed. Combined with the learning curve model, the technology diffusion model and expectations about future economic development in China, a new model, the renewable energy optimization model (REOM), is developed to analyse the development of three renewable energy sources (wind power, solar power and biomass power) from 2009 to 2020. Results show that (1) the maximum installed capacities of wind power, solar power and biomass power will reach 233,321, 26,680 and 35,506 MW in 2020; (2) from 2009 to 2020, biomass power will develop rapidly at the early stage while wind power is developed massively at the final stage and solar power has relatively stable growth; (3) due to the added capacity in the early periods, the unit investment cost of solar power shows a large decline, which is good for its following scale development; (4) the investment ratio constraint has a large effect on the development of wind power while the constraint of on-grid proportion of renewable energy generation has a significant effect on the development of wind power and solar power. The results have important policy implications for long-term energy planning in developing countries, such as China and India.

14/01175 Causality between public policies and exports of renewable energy technologies

Sung, B. and Song, W.-Y. *Energy Policy*, 2013, 55, 95–104.

This article investigates the causal relationship between public policies and exports of renewable energy technologies using panel data from 18 countries for the period 1991–2007. A number of panel unit root and cointegration tests are applied. Time series data on public policies and exports are integrated and cointegrated. The dynamic ordinary least squares results indicate that in the long run, a 1% increase in government R&D expenditures (RAD) increases exports (EX) by 0.819%. EX and RAD variables respond to deviations from the long-run equilibrium in the previous period. Additionally, the Blundell–Bond system generalized methods of moments is employed to conduct a panel causality test in a vector error-correction mechanism setting. Evidence of a bidirectional and short-run, and strong causal relationship between EX and the contribution of renewable energy to the total energy supply (CRES) is uncovered. CRES has a negative effect on EX, whereas EX has a positive effect on CRES. Some policy implications based on the results of this study are also suggested.

14/01176 Economic evaluation of forest biomass production in central Italy: a scenario assessment based on spatial analysis tool

Sacchelli, S. *et al. Biomass and Bioenergy*, 2013, 53, 1–10.

A spatial analysis tool, a decision support (DS) model able to support decision-making processes related to forestry energy planning has been developed using ecological and economic parameters. In this paper, the relative performance of different forest energy chains were compared by using metrics such as net revenue from forest processes, break-even prices of wood fuels, and the price elasticity of the bioenergy supply. Working with different scenarios at a spatial level, the DS model can evaluate innovative technologies and traditional forest harvest and logistical chains across a range of products, such as firewood and woodchips. The spatial analysis lends itself easily to an analysis of the political and administrative constraints with respect to levels of administration and regional variables. As expected, applying the tool to the Tuscany region in Italy shows that local characteristics and the species composition of an area influence the economic outcome of different harvest and logistical chains. In particular, mixed species Mediterranean forests appear to be suitable for the implementation of innovative bioenergy production processes, such as whole tree chipping.

14/01177 Estimation of tidal power potential

Walters, R. A. *et al. Renewable Energy*, 2013, 51, 255–262.

Several approaches can be used for estimating tidal power potential. From a theoretical point of view, others have shown that the problem can be reduced to a single or multiple boundary problem with simple geometry where each case has a well-defined maximum power potential. From a practical point of view, the potential can be approximated from the ambient flow. Questions naturally arise whether the theoretical approach can be applied to a typical field-scale problem, and whether the practical approach has any validity. In order to provide more insight into these questions, form drag representing tidal turbines has been introduced into a numerical flow model. This is an unstructured grid model with an implicit treatment of wetting and drying that has been shown to be robust, accurate, and efficient for highly irregular coastal ocean environments and is well suited for this problem. The field site that has been examined is Minas Passage in the Bay of Fundy which provides an interesting practical perspective for this problem. In the end, only a fraction of the theoretical maximum power potential can be realized in practice because of physical constraints on the maximum form drag for tidal turbines.

14/01178 Explaining the diffusion of renewable energy technology in developing countries

Pfeiffer, B. and Mulder, P. *Energy Economics*, 2013, 40, 285–296.

This study considers the diffusion of non-hydro-renewable energy (NHRE) technologies for electricity generation across 108 developing countries between 1980 and 2010. The authors use two-stage estimation methods to identify the determinants behind the choice of whether or not to adopt NHRE as well as about the amount of electricity to produce from renewable energy sources. They found that NHRE diffusion accelerates with the implementation of economic and regulatory instruments, higher per capita income and schooling levels, and stable, democratic regimes. In contrast, increasing openness and aid, institutional and strategic policy support programs, growth of electricity consumption, and high fossil fuel production appear to delay NHRE diffusion. Furthermore, the authors found that a diverse energy mix increases the probability of NHRE adoption. Finally, a weak support was found for a positive influence of the Kyoto Protocol on NHRE diffusion and no evidence for any influence resulting from financial sector development.

14/01179 Harmonizing biodiesel fuel standards in East Asia: motivations, progress and challenges

Shi, X. and Goto, S. *Applied Energy*, 2013, 105, 217–222.

This paper discusses the development of and policy towards biodiesel fuel (BDF) in the East Asia Summit (EAS) region (hereafter East Asia), with a focus on activities related to harmonizing BDF standards. To minimize problems with engines arising from the use of BDF, most EAS countries have established national BDF standards. However, these diverse standards cause barriers for BDF trade, and act against the regional interest in maximizing benefits from BDF production and utilization. Therefore, the East Asian policy-makers decided to harmonize BDF standards and a regional benchmark standard has been published. Through a comparative review of existing national standards against the benchmark, it finds that the harmonization is beneficial economically, and feasible technically, but stalled practically due to a lack of political determination. The key message from this paper is a call for political determination in East Asia to implement the harmonization. The findings of this paper may supplement the literature, enhance understanding of the East Asian case, and provide lessons and implications that may be helpful in advancing similar harmonization elsewhere.

14/01180 Hybrid renewable power systems for mobile telephony base stations in developing countries

Kusakana, K. and Vermaak, H. J. *Renewable Energy*, 2013, 51, 419–425.

This paper investigates the possibility of using hybrid photovoltaic (PV)–wind renewable systems as primary sources of energy to supply mobile telephone base transceiver stations in the rural regions of the Democratic Republic of Congo. For this purpose, three different areas not served by the grid namely: Kabinda, Mbuji-Mayi and Kamina where solar and wind resources are available, were selected as pilot sites to implement this study. Four different possible options including a hybrid PV–wind, a diesel generator, a pure photovoltaic and a pure wind energy system were designed to compare and evaluate their technical performance, economics and environmental impact. The proposed system was sized using 'the most unfavourable month method'. The system simulations were made with HOMER software using wind speeds, solar irradiance, and the load demand, components costs and technical specifications. The results of the hybrid system were compared with those of other supply options, using the initial capital, the total net present cost, the cost of energy and the capacity shortage as the main criteria of selection to supply the base transceiver stations (BTS) load. In the case of Kabinda for example, the hybrid system (composed of two 7.5 kW wind generators, 10 kW PV array, 7.5 kW inverter, and 82 batteries) has an initial capital cost of $119,250, a net present cost of $196,975, an operation cost of $3109 and a cost of energy produced of $0.372/kWh. For the duration of the project (20 years) the use of the hybrid power system is the most economical and is a well-suited solution to supply the load compared to the pure PV system, wind system and diesel generator options. Apart from being very expensive to maintain and operate, the diesel generator contributes to the pollution of the environment. The results of this study can be used as a tool for the deployment of a stand-alone hybrid PV–wind system to supply cost-effective electricity to the BTS load for network companies while protecting the environment in the remote areas of the Democratic Republic of Congo and other rural areas in the world, where wind and solar resources are available and exploitable.

14/01181 Importance of policy support and feedstock prices on economic feasibility of bioethanol production from wheat straw in the UK

Littlewood, J. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 291–300.

The economic feasibility of producing bioethanol from wheat straw in the UK using various state-of-the-art pretreatment technologies (steam explosion with and without acid catalyst, liquid hot water, dilute acid and wet oxidation) is assessed in this study. Under the current technology base-case modelled using high enzyme loadings demonstrated at the laboratory-scale, wet oxidation pretreatment had the lowest minimum ethanol selling price (MESP) of £0.347/L (US$2.032/gal). A contribution analysis showed feedstock price and enzyme cost were the two greatest contributors to the MESP, which led to a prospective case study and sensitivity analysis for assessing the effects of these two factors on the potential for economically competitive wheat straw-to-bioethanol UK supply chains. Prospective case studies modelled with a reduced enzyme loading and cost, demonstrated that although pretreatment scenarios with liquid hot water and steam explosion without acid catalyst were the closest to petrol-pump prices, policy support in the form of tax exemptions could significantly enhance competitiveness of bioethanol with conventional fuel. A sensitivity analysis of feedstock prices also demonstrated that access to wheat straw prices of £35/t or lower would allow bioethanol production to be competitive with petrol under the best case scenario.

14/01182 Influence of different practices on biogas sustainability

Boulamanti, A. K. *et al. Biomass and Bioenergy*, 2013, 53, 149–161.

Biogas production and use are generally regarded as a sustainable practice that can guarantee high greenhouse gas (GHG) savings. However, the actual carbon footprint of biogas is strongly influenced by several factors. The aim of this study is to analyse the environmental performance of different biogas to electricity scenarios. Two criticalities are identified as important: the choice of feedstock and the operational practice concerning the digestate. Maize, manure and co-digestion of them are the different feedstocks chosen. Maize has higher yields, but its cultivation has to be accounted for, which consists of 28–42% of the GHG emissions of the whole process of producing electricity. Manure is considered a residue and as a result benefits from no production stage, but also from avoided emissions from the normal agricultural practice of storing it in the farm and spreading it as fertilizer, but has lower methane yields. Co-digestion combines the benefits and disadvantages of the two different feedstocks. Digestate storage in open or closed tanks and further use as fertilizer is analysed. The environmental impact analysis shows that a substantial reduction of GHG emissions can be achieved with closed digestate storage. The GHG emissions savings vary from about 3% in the maize pathways with open storage up to 330% in the manure pathway with closed storage. The biogas pathways, though, have worse environmental performances in all other environmental impacts considered but ozone depletion potential when compared to the European electricity average mix.

14/01183 Integration of bioenergy systems into UK agriculture – new options for management of nitrogen flows

Skenhall, S. A. *et al. Biomass and Bioenergy*, 2013, 54, 219–226.

The large flow of reactive nitrogen (N) through agriculture causes negative environmental impacts, pointing to a need for changes in agricultural practices. At the same time, agriculture is expected to provide biomass to support the increasing demand from the UK bioenergy sector. A high-level aggregated model of the agricultural system in the UK was developed, which maintains the existing level of food and livestock production and at the same time increases N recirculation. Integrating three different bioenergy sub-systems into the agricultural system was an essential component of the model development. Cellulosic bioenergy crops were located in the landscape as vegetation filters to intercept and capture N and thereby reduce N leaching. Efficient collection and digestion of manure produced organic N fertilizer and biogas. Efficient forage production for cattle allowed further cultivation of bioenergy plants. Five implementation scenarios were developed to clarify the contribution of these bioenergy sub-systems to improved N management. The results point to a significant potential for improving the productive use of reactive N and for decreasing N losses to water and air. The interception and recirculation of N presently leaching from arable fields is assessed as the most important option. It is also important to increase recirculation of N in manure and in bioenergy system by-flows. Besides mitigating the environmental impacts of agriculture these measures reduce the requirements for newly synthesized N fertilizers. A systems perspective on N, agriculture, and bioenergy systems facilitates N recirculation and promotes effective N use, reducing the need for additional N inputs.

14/01184 Is it economically feasible for farmers to grow their own fuel? A study of Camelina sativa produced in the western United States as an on-farm biofuel

Keske, C. M. H. *et al. Biomass and Bioenergy*, 2013, 54, 89–99.

This paper models the economic feasibility of growing the oilseed crop *Camelina sativa* (‘camelina’) in the western USA to produce value-added protein feed supplement and a straight vegetable oil (SVO)-based biofuel. Modelled in eastern Colorado, this study demonstrates that camelina can be grown profitably both as a commodity and as an energy biofuel. These findings, along with the stochastic crop rotation budget and profitability sensitivity analysis, reflect unique contributions to the literature. The study’s stochastic break-even analysis demonstrates a 0.51 probability of growing camelina profitably when diesel prices reach $1.15/L. Results also show that the sale of camelina meal has the greatest impact on profitability. Yet once the price of diesel fuel exceeds $0.90/L, the farmer generates more revenue from the ability to offset diesel fuel purchases than the revenues generated from the sale of camelina meal. A risk analysis using second degree stochastic dominance demonstrates that a risk-averse farmer would choose to grow camelina if the price of diesel equals or exceeds $1.31/L. This paper concludes that camelina can offset on-farm diesel use, making it economically feasible for farmers to grow their own fuel. As a result, camelina production may increase farm income, diversify rural economic development, and contribute to the attainment of energy policy goals.

14/01185 Marine renewable energy and Scottish west coast fishers: exploring impacts, opportunities and potential mitigation

Alexander, K. A. *et al. Ocean & Coastal Management*, 2013, 75, 1–10.

There is currently a strong political drive for the development of the marine renewable energy industry in Europe, particularly in Scotland. However, little is known regarding the potential impacts and opportunities for the fishing industry. Furthermore, there has been little discussion of potential mitigation measures. In depth interviews were conducted with fishers based on the west coast of Scotland to address the gap in knowledge of the potential conflict between offshore renewable energy development and commercial fishers. The key aim of this study was to ascertain the underlying needs of fishers. Three key issues were identified: (i) a potential loss of livelihood is of largest concern to fishers; (ii) skills shortages are a potential problem should a loss of livelihood occur; and (iii) fishers have varied opinions regarding the potential benefits arising from offshore renewable energy induced changes to the ecosystem. The key needs of fishers were determined to be continued security of employment and income, and control of one’s own life through decision-making based on fact. However, further research is required to answer the question: how can these basic needs be satisfied?.industry

14/01186 Methodology for tidal turbine representation in ocean circulation model

Roc, T. *et al. Renewable Energy*, 2013, 51, 448–464.

The present method proposes the use and adaptation of ocean circulation models as an assessment tool framework for tidal current turbine (TCT) array layout optimization. By adapting both momentum and turbulence transport equations of an existing model, the present TCT representation method is proposed to extend the actuator disc concept to three-dimensional large-scale ocean circulation models. Through the reproduction of experimental flume tests and grid dependency tests, this method has shown its numerical coherence as well as its ability to simulate accurately both momentum and turbulent turbine-induced perturbations in both near and far wakes in a relatively short period of computation time. Consequently, the present TCT representation method is a very promising basis for the development of a TCT array layout optimization tool.

14/01187 Micro-algae cultivation for biofuels: cost, energy balance, environmental impacts and future prospects

Slade, R. and Bauen, A. *Biomass and Bioenergy*, 2013, 53, 29–38.

Micro-algae have received considerable interest as a potential feedstock for producing sustainable transport fuels (biofuels). The perceived benefits provide the underpinning rationale for much of the public support directed towards micro-algae research. Here the authors examine three aspects of micro-algae production that will ultimately determine the future economic viability and environmental sustainability: the energy and carbon balance, environmental impacts and production cost. This analysis combines systematic review and meta-analysis with insights gained from expert workshops. Achieving a positive energy balance was found to require technological advances and highly optimized production systems. Aspects that will need to be addressed in a viable commercial system include: energy required for pumping, the embodied energy required for construction, the embodied energy in fertilizer, and the energy required for drying and de-watering. The conceptual and often incomplete nature of algae production systems investigated within the existing literature, together with limited sources of primary data for process and scale-up assumptions, highlights future uncertainties around micro-algae biofuel production. Environmental impacts from water management, carbon dioxide handling, and nutrient supply could constrain system design and implementation options. Cost estimates need to be improved and this will require empirical data on the performance of systems designed specifically to produce biofuels. Significant (>50%) cost reductions may be achieved if CO_2, nutrients and water can be obtained at low cost. This is a very demanding requirement, however, and it could dramatically restrict the number of production locations available.

14/01188 Overall review of pumped-hydro energy storage in China: status quo, operation mechanism and policy barriers

Ming, Z. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 35–43.

With the integration of increased variable renewable energy generation and advent of liberalized electricity market, much attention has been devoted on the development of pumped hydro energy storage (PHES) as it has many prominent advantages of ensuring the safe and steady operation of power grid. In China, PHES has met a booming periods for the last 10 years. Currently, there are 24 PHES stations with an installed capacity of 16.95 GW while government’s target of 2020 is 50.02 GW. In this paper, an overall review of China’s PHES development is provided with a detailed presentation of the installed capacity and distribution of existing and proposed PHES stations, four typical stations are examined in order to give a good description for the practical functions of PHES in power grid, the management mode and price mechanism of PHES operation are analysed and the barriers in

PHES development in China considered. The State Grid Corporation of China is making great efforts in China's PHES development, and is discussed as a role model. It is suggested that PHES should be temporarily operated and scheduled by grid companies, while the government should also subsidize the stations' operation to relieve the price pressure of the ever-growing integration of renewable energy.

14/01189 Scientific production of renewable energies worldwide: an overview

Manzano-Agugliaro, F. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 134–143.

This paper reviews the scientific production of renewable energies, namely, solar, wind, biomass, hydropower and geothermal, from 1979 to 2009. The production of all the countries in the world is analysed, paying particular attention to renewable energies and research institutions. The production of scientific research for each type of energy is represented on world maps to show the degree of relationship between this research and the resources of these energies. It is observed that biomass is the most studied, both by number of publications, with 56% of the publications on renewable energy, and by geographical distribution. The next in importance by number of publications is solar energy (26%). The countries investigating solar energy, however, are not necessarily those with the greatest availability of this resource. Wind is the third positioned in publication (11%). Wind is being investigated by countries that most have implemented this type of energy production. Hydro and geothermal energies are also investigated by countries with great abundance of this resource. It is observed that research on renewable energy is highly concentrated in a few countries (12 or 14, depending on the energy type), accounting for between 70% and 80% of scientific production. The role of the USA as a leader in research in all renewable energies studies is emphasized with NASA being the leading institution for solar and wind energy. The Chinese Academy of Sciences leads in hydropower and biomass, and the US Geological Survey leads in geothermal energy.

14/01190 Strategic value optimization and analysis of multi-product biomass refineries with multiple stakeholder considerations

Sharma, P. *et al. Computers & Chemical Engineering*, 2013, 50, 105–129.

The commercialization of cellulosic biofuels has been plagued by multiple sources of market and technology uncertainty, and the lack of capital. It is conjectured that government support for renewable fuels' has concealed the true market value of its producers, and its removal will lead to a slew of enterprise failures destroying significant private and taxpayer wealth. With such uncertainty, it is prudent to carefully evaluate capital investments in new facilities before actual investment is incurred. This paper presents a strategic optimization model for a multi-product biomass refinery that optimizes the long-term value of the facility to its stakeholders while yielding optimal decisions for input feedstock mix, product portfolio, conversion technology and process configuration, and capital structure for financing. The paper promotes the concept of stakeholder value, where actors at different supply chain nodes are included as a part of a co-operative enterprise, as a means to spread risks across the supply chain.

14/01191 The contribution of hydropower in meeting electric energy needs: the case of Turkey

Akpinar, A. *Renewable Energy*, 2013, 51, 206–219.

In this article, an attempt is made to better understand the contribution of hydropower in meeting electric energy needs of Turkey. Thus, a comparison between Turkey and other countries, which have some similarities with Turkey or which are more developed nations compared to Turkey, for evaluating from different aspects the contribution of hydropower in meeting electric energy needs is performed. The producers of electricity and hydroelectricity in the world, and the electric sectors of all the selected countries are firstly examined. Thereafter, Turkey's water resources and its potential, hydropower potential, and current status of hydropower in Turkey are investigated in detail. A detailed discussion regarding economic and energy indicators, hydroelectricity versus thermal electricity, the contributions of hydroelectricity to the total and renewable electricity generation, and the usage status of hydro potential of each selected nation is also made. Finally, it is found that hydropower is the second largest contributor in meeting Turkey's electric energy needs after thermal, mainly natural gas. It is also estimated that the contribution of hydropower will continue because a vast amount of its economically feasible hydro potential (about 64%) is undeveloped. Besides, it is determined that the contribution of hydropower in the total electricity generation in Turkey is greater than that of China and India, but it is lower than that of Norway, Brazil, and Canada.

14/01192 The impact of plant size and location on profitability of biogas plants in Germany under consideration of processing digestates

Delzeit, R. and Kellner, U. *Biomass and Bioenergy*, 2013, 52, 43–53.

The production of bioenergy is considered to be a promising energy source for a sustainable energy mix and it is politically promoted in many countries. With the exception of Brazilian ethanol, bioenergy is not competitive with fossil energy sources, and therefore needs to be subsidized. Several types of bioenergy are based on bulky raw biomass with high per unit transport costs, importantly impacting on the plant's production costs and profitability. In addition, considerable quantities of digestates are released, causing disposal costs. Various studies in the past aimed primarily at analysing transport costs of inputs. This paper focuses on disposal costs of fermentation digestates from biogas production in Germany and analyse different processing techniques and their impact on profitability for three plant size in three case study areas. The results show that especially in regions with only a small amount of agricultural land and a large heterogeneity in its agricultural area, processing of digestates increases the profitability of biogas production. The same accounts for regions with high livestock density, where the area needed for disposal is comparatively large. The cost efficiency is enforced by a high share of animal excrements on input and the biogas plant size.

14/01193 Tidal effect compensation system for point absorbing wave energy converters

Castellucci, V. *et al. Renewable Energy*, 2013, 51, 247–254.

Recent studies show that there is a correlation between water level and energy absorption values for the studied wave energy converters: the absorption decreases when the water levels deviate from average. The situation appears during tides when the water level changes significantly. The main objective of the paper is to present a first attempt to increase the energy absorption during tides by designing and realizing a small-scale model of a point absorber equipped with a device that is able to adjust the length of the rope connected to the generator. The adjustment is achieved by a screw that moves upwards in the presence of low tides and downwards in the presence of high tides. Numerical results as well as experimental tests suggest that the solution adopted to minimize the tidal effect on the power generation shows potential for further development.

14/01194 Variability and phasing of tidal current energy around the United Kingdom

Iyer, A. S. *et al. Renewable Energy*, 2013, 51, 343–357.

Tidal energy has the potential to play a key role in meeting renewable energy targets set out by the British government and devolved administrations. Attention has been drawn to this resource as a number of locations with high tidal current velocity have recently been leased by the Crown Estate for commercial development. Although tides are periodic and predictable, there are times when the current velocity is too low for any power generation. However, it has been proposed that a portfolio of diverse sites located around the UK will deliver a firm aggregate output due to the relative phasing of the tidal signal around the coast. This paper analyses whether firm tidal power is feasible with 'first generation' tidal current generators suitable for relatively shallow water, high velocity sites. This is achieved through development of realistic scenarios of tidal current energy industry development. These scenarios incorporate constraints relating to assessment of the economically harvestable resource, tidal technology potential and the practical limits to energy extraction dictated by environmental response and spatial availability of resource. The final scenario is capable of generating 17 TWh/year with an effective installed capacity of 7.8 GW, at an average capacity factor of 29.9% from seven major locations. However, it is concluded that there is insufficient diversity between sites suitable for first generation tidal current energy schemes for a portfolio approach to deliver firm power generation.

14/01195 Wave power variability over the northwest European shelf seas

Neill, S. P. and Hashemi, M. R. *Applied Energy*, 2013, 106, 31–46.

Regional assessments of the wave energy resource tend to focus on averaged quantities, and so provide potential developers with no sense of temporal variability beyond seasonal means. In particular, such assessments give no indication of inter-annual variability – something that is critical for determining the potential of a region for wave energy convertor (WEC) technology. Here, the authors applied the third-generation wave model SWAN (Simulating Waves Nearshore) at high resolution to assess the wave resource of the northwest European shelf seas, an area where many wave energy test sites exist, and where many wave energy projects are under development. The model was applied to 7 years of wind forcing (2005–2011), a time period which witnessed considerable extremes in the variability of the wind (and hence wave) climate, as evidenced by the variability of the North Atlantic Oscillation (NAO). The simulations demonstrated that there is much greater uncertainty in the north-west European shelf wave resource during October to March, in contrast to the period April to September. In the more energetic regions of the north-west European shelf seas, e.g. to the north-west of Scotland, the uncertainty was considerably greater. The winter north-west European shelf wave power resource correlated well with the NAO. Therefore, provided trends in the NAO can be identified over the coming decades, it may be possible to estimate how the European wave resource will similarly vary over this time period. Finally, the magnitude of wave power estimated by this study was around 10% lower than a resource which is used extensively by the wave energy sector – the Atlas of UK Marine Renewable Energy Resources. Although this can partly be explained by different time periods analysed for each study, the application of a third-generation wave model at high spatial and spectral resolution significantly improved the representation of the physical processes, particularly the non-linear wave–wave interactions.

14/01196 Wind energy and environmental assessments – a hard look at two forerunners' approaches: Germany and the United States

Geißler, G. *et al. Renewable Energy*, 2013, 51, 71–78.

Wind energy development is booming worldwide with Germany and the USA being forerunners in installed capacity. Based on a review of relevant laws and regulations, policy, siting, and permitting documents, academic literature, and expert interviews, the paper compares the permit and environmental impact assessment (IA) policies and regulations pertaining to wind energy projects in both countries. The focus is on the potential of IAs in supporting an environmentally conscious development of wind power generation. This includes the analysis of IA regulations on the project level, strategic level impact assessment and planning processes, opportunities for public involvement and transparency of processes, and the clarity and predictability of the IA provisions. The findings suggest certain variations between both countries' permit and IA processes for wind energy projects and further research needs, *inter alia* on the actual effects of strategic assessment of wind development on subsequent permitting.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

14/01197 A multi-period optimization model for optimal planning of China's power sector with consideration of carbon mitigation – the optimal pathway under uncertain parametric conditions

Zhang, D. *et al. Computers & Chemical Engineering*, 2013, 50, 196–206.

Optimal planning of power industry considering carbon mitigation for a long-term future is complex, involving many technical alternatives and infinite possible plants installations, retrofitting, and decommissions. Previously the authors built a multi-period superstructure optimization planning model of China's power sector, gaining the optimal pathway of China's power sector with fixed parametric input during 2010–2050. With that model, this paper attempted to optimize pathway of China's power sector under uncertainty, in which the most influential parameters were uncertain. A levelized optimal pathway of China's power sector was gained, reliability of which was verified by comparing it with optimal results for the stochastic samples. The levelized optimal pathway showed that in the presence of carbon tax, carbon emissions of the power sector were reduced significantly by developing low-carbon technologies including nuclear power, renewables, as well as carbon capture and sequestration (CCS), and CCS would be key to reduce carbon emissions from coal power.

14/01198 Analysis and numerical investigation of two dynamic models for liquid chromatography

Javeed, S. *et al. Chemical Engineering Science*, 2013, 90, 17–31.

This paper presents the analytical and numerical investigations of two established models for simulating liquid chromatographic processes namely the equilibrium dispersive and lumped kinetic models. The models are analysed using Dirichlet and Robin boundary conditions. The Laplace transformation is applied to solve these models analytically for single component adsorption under linear conditions. Statistical moments of step responses are calculated and compared with the numerical predictions for both types of boundary conditions. The discontinuous Galerkin finite element method is proposed to numerically approximate the more general lumped kinetic model. The scheme achieves high order accuracy on coarse grids, resolves sharp discontinuities, and avoids numerical diffusion and dispersion. For validation, the results of the suggested method are compared with some flux-limiting finite volume schemes available in the literature. A good agreement of the numerical and analytical solutions for simplified cases verifies the robustness and accuracy of the proposed method. The method is also capable to solve chromatographic models also for non-linear and competitive adsorption equilibrium isotherms.

14/01199 Annealing of ion irradiation damage in nuclear graphite

Lasithiotakis, M. *et al. Journal of Nuclear Materials*, 2013, 434, (1–3), 334–346.

Changes in Raman spectra of polished and ion-irradiated gilsocarbon and highly orientated pyrolytic graphite (HOPG) during annealing have been investigated and compared with changes reported during stored energy release in fast neutron irradiated graphite. It is postulated that the change in the Raman spectra of polished, ion-irradiated and neutron-irradiated graphite can be attributed to crystalline structural changes due to the annealing of lattice defects. This is illustrated by changes in the kinetic parameters, in terms of the decrease of the Raman I_D/I_G ratio, during the thermal annealing of polished and ion-irradiated Gilsocarbon and HOPG graphite. Several kinetic models are investigated in terms of activation energy and order of reaction. The most suitable model to explain Raman annealing kinetics was found to be, a two-reaction model for polished Gilsocarbon graphite, and a two and possibly three reaction model for ion-irradiated Gilsocarbon graphite and ion-irradiated HOPG. The kinetics parameters obtained using both the two and three reaction models reveal similarities with kinetic models obtained for neutron irradiated graphite. The assumption that the Raman intensity ratio I_D/I_G is proportional to the square root of the defect quantity provided a better fit than the assumption of direct proportionality.

14/01200 Constant pressure hydraulic energy storage through a variable area piston hydraulic accumulator

Van de Ven, J. D. *Applied Energy*, 2013, 105, 262–270.

Hydraulic accumulators are used in a variety of applications to minimize the pressure variation in hydraulic circuits and to store energy. Conventional hydraulic accumulators suffer from two major limitations, the hydraulic system pressure varies with the quantity of energy stored and the energy density is significantly lower than other energy domains. In this paper, a novel hydraulic accumulator is presented that uses a piston with an area that varies with stroke to maintain a constant hydraulic system pressure while the gas pressure changes. The variable area piston is sealed with a fabric reinforced rolling diaphragm. In this work, the piston radius profile is developed as a function of the piston displacement and then transformed into a function of the axial contact location between the piston and the diaphragm. The piston profile was solved numerically for a variety of conditions using both transformation methods to illustrate the geometric design trade-offs. Using a variable area gas piston with a fixed cylinder area, the maximum gas volume ratio was 1.8 : 1. An analysis of the energy density revealed that the constant pressure accumulator provides a 16% improvement in energy density over a conventional accumulator at a volume ratio of 2.71 : 1 and also exceeds the maximum energy density of a conventional accumulator at the lower volume ratio of 1.8 : 1. This new promising technology maintains a constant hydraulic system pressure independent of the quantity of energy stored, easing system control and allowing other circuit components to be downsized to meet the same power requirements, while also increases the energy storage density.

14/01201 Continuous production of single enantiomers at high yields by coupling single column chromatography, racemization, and nanofiltration

Nimmig, S. and Kaspereit, M. *Chemical Engineering and Processing: Process Intensification*, 2013, 67, 89–98.

A process combining single-column chromatography, racemization and solvent removal by membrane filtration to produce single enantiomers at high yields is proposed and investigated. Shortcut design methods are developed for a basic design using only a single chromatogram as input without the need for dynamic process simulation. A detailed process model is used to elucidate the role of relevant parameters and process dynamics. Experimental investigation of the process in fully coupled operation demonstrate the capability of the concept to produce single enantiomers at high yield and purity, as well as the applicability of the proposed design methods.

14/01202 Dynamic modeling of a multilayer rotating blade via quadratic layerwise theory

Sun, J. *et al. Composite Structures*, 2013, 99, 276–287.

A novel dynamic model for a multilayer rotating blade mounted at an arbitrary stagger angle using a quadratic layerwise theory is developed to study structural dynamics of the blade, particularly damping properties, using various coating layer configurations. A reduced two-dimensional (2D) model is used to describe the dynamic behaviour of each layer in the weak form, while the quadratic layerwise theory is applied to interpolate the transverse shear stresses along the thickness direction. Results of numerical simulations with the reduced 2D model are compared to the full three-dimensional model showing an excellent agreement, comparable to the cubic layerwise theory, for both modal analysis and frequency response calculations. Moreover, damping analyses are performed on two types of multilayer blades: two-layer (free damping) and three-layer (constrained layer), in both non-rotating and rotating situations, and, parametric analyses with varying coating thickness and rotation speed are carried out. It is shown that damping decreases as the rotation speed increases due to inertial and Coriolis effects. Furthermore, frequency loci veering as a result of the rotation speed is observed. The proposed model gives an efficient and accurate way to study the dynamic behaviour of rotating multilayer structures, such as compressor blades.

14/01203 Electrical and thermo-mechanical analysis of beam recovery system for megawatt power gyrotron

Bhattacharya, R. *et al. Fusion Engineering and Design*, 2013, 88, (4), 253–257.

The paper presents the electrical and thermo-mechanical design of single-stage beam recovery system for 120 GHz, 1 MW gyrotron. The electrical study shows that the cylindrical shape single-stage beam recovery system enhances the efficiency by 66.26%. The maximum power deposited to collector in depressed collector operation is 0.48 MW for electronic efficiency, 30% and 1.44 MW for DC electron beam. The thermo-mechanical analysis has been performed to evaluate the water cooling system. The cooling system has capability of accommodating a peak wall loading, 0.9 kW/cm^2 at flow rate of 1500 l/min for safe operating time, 60 ms. Further, a high voltage analysis is also carried out to appraise the electric field distribution in the collector.

14/01204 Flapping dynamics of a low aspect-ratio energy-harvesting membrane immersed in a square cylinder wake

Shi, S. *et al. Experimental Thermal and Fluid Science*, 2013, 46, 151–161.

A flexible polyethylene terephthalate membrane, with a low aspect-ratio of 1.67, located within the wake region of a square cylinder is studied to understand the effects of Reynolds number ($Re_D = 3200$–12,000) on its resultant flapping behaviour and strain energy distribution. For Reynolds number up to $Re_D = 4000$, the membrane exhibits limited cantilever-like oscillations (i.e. mode A), while a mixture of mode A response and limited travelling waves is produced between $Re_D = 4000$ and 6800 (i.e. mode B). On the other hand, quasi-periodical flapping occurs between $Re_D = 6800$ and 12,000 (i.e. mode C). Results further demonstrate similarities to high aspect-ratio polyvinylidene difluoride membranes studied previously: first, flapping amplitude increases with Reynolds number and second, an optimal flapping frequency exists in mode C whereby it ‘locks-in’ to the wake vortex-shedding frequency. Flapping intermittencies are observed to occur in all modes and found to decrease with increasing Reynolds number. In addition, non-uniform strain energy distributions along the membrane length and the total harvestable energy levels are deduced to increase with the Reynolds number. Finally, results also indicate that modes A and B lead to linear energy growth rates, while mode C produces growth rates that scales with $Re_D^{3.4}$.

14/01205 Generalized thermal resistance and its application to thermal radiation based on entransy theory

Wu, J. and Cheng, X. *International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 374–381.

Entransy is a novel concept developed in recent years to measure the transport ability of heat in heat transfer processes. In order to analyse and optimize thermal radiation process more conveniently and intuitively, the authors develop the entransy-theory-based method to the field of thermal radiation problems to define the generalized thermal resistance for multi-dimensional steady state thermal radiation systems, with a consistent dimension of those for heat conduction and convection systems proposed in previous studies. Based on it, the minimum generalized thermal resistance principle for thermal radiation is developed and its equivalence with the entransy dissipation extremum principle can be concluded by defining the concept of heat flux weighted average temperature difference for thermal radiation systems. The authors note that these two principles emphasize particularly on the optimization of the mean performance for heat transfer processes. A steady state thermal radiation process in an enclosure with three opaque surfaces is taken as an example to illustrate the applicability and reliability of generalized thermal radiation resistance when it is used to optimize thermal radiation problems. Finally, a comparison between the principles of minimum generalized thermal resistance and minimum entropy generation is discussed to show that the latter might not be appropriate to optimize some thermal radiation problems.

14/01206 How sensitive to time period sampling is the asymmetric price response specification in energy demand modelling?

Adofo, Y. O. *et al. Energy Economics*, 2013, 40, 90–109.

The purpose of this paper is to investigate the criticism that energy demand estimates based on a specific price decomposition are sensitive to the chosen time period used for the estimation. To analyse this in a systematic way, different time series sample periods are constructed from annual data for 17 OECD countries covering the overall period 1960 to 2008. The specific price decomposition under consideration, often used to estimate asymmetric price response models of energy demand, separates the impact of prices above the previous maximum, of a price recovery below the previous maximum and of a price cut. Therefore, the analysis does not just involve using different time periods; instead, for each time period investigated, a new dataset is constructed and for each dataset, the price variable is decomposed in this way. An energy demand relationship allowing for asymmetric price responses is therefore estimated for each different sample period and the results suggest that recalculation of the decomposed price variables for each different period does affect the stability of the estimated energy demand responses. In contrast, a similarly estimated energy demand relationship with symmetric price responses for each different sample period is found to have less instability.

14/01207 Imaging in the optically dense regions of a spray: a review of developing techniques

Linne, M. *Progress in Energy and Combustion Science*, 2013, 39, (5), 403–440.

Since the year 2000, a number of very different techniques to image spray formation in optically dense regions of atomizing sprays have appeared in the literature, been further developed, and applied to sprays. Three of them are transillumination techniques (meaning a beam is passed all the way through the spray and imaged on the other side, often called ‘line-of-sight’), one technique is internally illuminated (the signal originates inside the spray), and one is a planar laser imaging technique. The view expressed in this paper is that four of the techniques are highly complementary. When used together with the existing techniques for the rest of the spray, it has finally become possible to describe the entire spray flowfield from inside a nozzle to the very tip of the vapour cloud, including combustion characterization when appropriate.

14/01208 Integration of control theory and scheduling methods for supply chain management

Subramanian, K. *et al. Computers & Chemical Engineering*, 2013, 51, 4–20.

This paper proposes distributed model predictive control for supply chain optimization. In particular, this study focuses on inventory management in supply chains. The authors use cooperative model predictive control, in which each agent makes their local decisions by optimizing the overall supply chain objective. Motivated by a recent study, the authors develop a new cooperative model predictive control (MPC) algorithm that is applicable to any stabilizable system, and in particular to supply chain models. The authors illustrate cooperative MPC for a two-node supply chain example and compare its performance and properties with other classical distributed operating policies.

14/01209 Ion transport restriction in mechanically strained separator membranes

Cannarella, J. and Arnold, C. B. *Journal of Power Sources*, 2013, 226, 149–155.

This study used AC impedance methods to investigate the effect of mechanical deformation on ion transport in commercial separator membranes and lithium-ion cells as a whole. A Bruggeman-type power law relationship was found to provide an accurate correlation between porosity and tortuosity of deformed separators, which allows the impedance of a separator membrane to be predicted as a function of deformation. By using mechanical compression to vary the porosity of the separator membranes during impedance measurements it was possible to determine both the α and γ parameters from the modified Bruggeman relation for individual separator membranes. From impedance testing of compressed pouch cells it was found that separator deformation accounts for the majority of the transport restrictions arising from compressive stress in a lithium-ion cell. Finally, a charge state dependent increase in the impedance associated with charge transfer was observed with increasing cell compression.

14/01210 Mixing energy investigations in a liquid vessel that is mixed by using a rotating magnetic field

Rakoczy, R. *Chemical Engineering and Processing: Process Intensification*, 2013, 66, 1–11.

The purpose of the present report is, first, to develop the basic equations and similarity criteria governing the mixing system with the magnetic particles under the effect of a rotating magnetic field (RMF);

second, to carry out the experimental investigations dealt with the power consumption and mixing time under the action of RMF. Dimensionless correlations are proposed to predict power consumption and the mixing time in the analysed mixing system. The study relates to the mixing energy defined as the product of the power input and the mixing time in a tested experimental set-up. The data obtained for mixing efficiency was correlated in terms of the modified Reynolds number which can be used for predictions of mixing process in systems with the magnetic particles. The magnetic particle may be treated as a miniaturized mixer and it may offer a unique alternative approach to mixing. The satisfactory comparison indicates that the mixing process under the action RMF has the significantly higher of the energy consumption than the classical agitators.

14/01211 Natural ventilation characteristics of one-sided wind catchers: experimental and analytical evaluation

Dehghan, A. A. *et al. Energy and Buildings*, 2013, 61, 366–377.

Wind tunnel experiments, flow visualization tests as well as analytical modelling are conducted to investigate the influence of wind speed and its direction on the ventilation capacity of one-sided wind-catcher models. These are wind-catchers with flat, inclined and curved roofs which are in common use in central part of Iran for passive cooling. Induced airflow rate and pressure coefficients over all the internal surfaces of the wind-catchers' channels are measured. Using measured pressure coefficients and analytical modelling, natural ventilation efficiencies of wind-catchers are calculated and compared with the experimental measurements. It is seen that for all wind directions, the semi-analytical prediction of ventilation efficiencies has a good agreement with the experimental results. Based on the measured quantities, it is shown that the flow pattern, the internal pressure field and induced airflow rate inside the wind-catchers are strongly influenced by the geometry of wind-catcher's roof and the approaching wind direction. Measured airflow rate inside the wind-catcher revealed that for zero air incident angle, the one with curved roof is capable of capturing higher airflow while for high values of air incident angles, the inclined roof wind-catcher is more suitable and less sensitive to changing the outdoor wind direction.

14/01212 Parametric analysis and optimization of entropy generation in unsteady MHD flow over a stretching rotating disk using artificial neural network and particle swarm optimization algorithm

Rashidi, M. M. *et al. Energy*, 2013, 55, 497–510.

The present study first of all concerns the first and second law analyses of an electrically conducting fluid past a rotating disk in the presence of a uniform vertical magnetic field, analytically via homotopy analysis method (HAM), and then applies artificial neural network (ANN) and particle swarm optimization (PSO) algorithm in order to minimize the entropy generation. In the first part of this study, entropy generation equation is derived as a function of velocity and temperature gradients and non-dimensionalized using geometrical and physical flow field-dependent parameters. A very good agreement can be seen between some of the obtained results of the current study and the results of the previously published data. The effects of physical flow parameters such as magnetic interaction parameter, unsteadiness parameter, disk stretching parameter, Prandtl number, Reynolds number and Brinkman number on all fluid velocity components, temperature distribution and the averaged entropy generation number are checked and analysed. For minimizing the entropy generation value a procedure based on ANN and PSO is proposed. This procedure comprises three steps. The first step is to find entropy generation for values of some different affecting factors. In the second step, some distinct multi-layer perceptron ANNs based on the data obtained from step one are trained. In step three, PSO is used to minimize the entropy generation in the considered stretchable rotating disk.

14/01213 Radiation damage of tungsten surfaces by low energy helium atom bombardment – a molecular dynamics study

Li, M. *et al. Journal of Nuclear Materials*, 2013, 433, (1–3), 17–22.

Molecular dynamics (MD) simulations were performed to study the radiation damage of tungsten surfaces bombarded by low energy (20–200 eV) helium atoms at various temperatures. Although the incident energy of the helium atoms is lower than the threshold energy that was thought to be required to induce damage on tungsten surfaces, the simulation results indicate that some W atoms are displaced from their initial lattice sites and stack on the top of the surfaces, leaving behind vacancies or helium occupants. Primary knock-on and the replacement sequence along the $\langle 1\,1\,1 \rangle$ direction are the two main mechanisms inducing this stacking of tungsten atoms. The threshold energy that is needed to initiate a knock-on tungsten atom at different depths below the surface and produce a stacking tungsten atom atop the surface has been calculated to better understand the observations. Studies on the effects of the substrate temperature and the incident energy indicate that increasing the substrate temperature increases the probability of generating stacking tungsten atoms on the surface, and the most probable range of the incident energy for generating such surface damage is between 50 and 80 eV.

14/01214 Recent developments in experimental (PIV) and numerical (DNS) investigation of solid–liquid fluidized beds

Reddy, R. K. *et al. Chemical Engineering Science*, 2013, 92, 1–12.

Particle image velocimetry measurements have been performed in a solid–liquid fluidized bed in the Reynolds number range of 51–759. To do this, the refractive indexes of the solid and liquid phases were matched at approximately 1.47 using 3 mm diameter borosilicate glass beads and a solution of turpentine and tetra-hydronaphthalene. Paraffin oil was added in varying quantities to vary the dynamic viscosity between 0.0012 and 0.010 Pa s without changing the refractive index of the solution. From the particle image velocimetry measurements, at sampling rates of 2 Hz, the fluctuating velocity components were found to be quite uniform in both the axial and radial directions. Moreover, the computed turbulent kinetic energy dissipation rates were also found to be relatively constant throughout the bed, thus highlighting the homogenous nature of the turbulence within the system. Following from an earlier study, direct numerical simulations were undertaken at particle Reynolds numbers up to 200 for assemblages of 1, 9, 27, 100, 180 and 245 particles, which corresponded to a liquid volume fraction range of $0.687 > \epsilon_L > 0.998$. The effect of surrounding particles on the settling velocity (hindrance effect) and the wake dynamics was investigated. It was found that the average settling velocity decreased with an increasing number of particles, with the quantitative results being in good agreement with a well-established empirical correlation. The local energy dissipation rate was also computed, and for a particle Reynolds number of 51, it was found to be $5.5\,\mathrm{m^2\,s^{-3}}$. This value was approximately 18 times the average energy dissipation rate of $0.30\,\mathrm{m^2\,s^{-3}}$; and compared favourably with the $0.36\,\mathrm{m^2\,s^{-3}}$obtained by a volume-averaged energy balance of the experimental system.

14/01215 Selection of controlled variables: a novel perspective based on the singular energy of weighted graphs

Zumoffen, D. and Musulin, E. *Computers & Chemical Engineering*, 2013, 56, 80–88.

The optimal selection of controlled variables is a well-known plant-wide control subproblem. In this paper, a novel approach based on spectral graph theory is proposed. This strategy is useful from both graphical and mathematical point of views. It is shown here that if the closed-loop process is represented by a specific weighted graph, deviations in plant variables are bounded by the graph singular energy. Moreover, this graph-based methodology supports the fast interpretation of the magnitude and direction of influences between process variables at steady state. The suggested spectral approach is compared with the recently proposed minimum square deviation methodology in detail. Indeed, both strategies have strong structural and behavioural resemblances, i.e. reducing specific deviations and improving the conditions of the subprocess to be controlled. The introduced graph representation is tested in the Shell oil fractionator process, giving a complete set of evaluations and results.

14/01216 Technical details regarding the design, the construction and the operation of seawater pumped storage systems

Al. Katsaprakakis, D. *et al. Energy*, 2013, 55, 619–630.

This paper presents important technical details for the design, construction and operation of seawater pumped storage systems (S-PSS). S-PSS co-operating with wind parks, features as the most promising technology towards maximizing renewable energy penetration in insular systems with low annual rainfalls. This paper summarizes the fundamental points of integrated studies of S-PSS, from the feasibility study to the precise positioning of the systems' components and the selection of the main equipment. Special issues regarding the use of seawater from the PSS (pumped storage system), such as the use of materials for the construction of the penstock, the construction of the upper reservoir, placing the pump station and the hydro power plant on the coast and the selection of pump and hydro-turbine models are presented thoroughly. Indicative results are presented from two S-PSS of small and medium size. The study proves that current technology enables the secure use of seawater in PSS. The electricity surplus from wind powered pumped storage systems (WP-PSS) can also be exploited in reverse osmosis desalination plants for producing potable water. Seawater can be pumped directly from the sea, thus construction of a lower reservoir is avoided, compensating higher costs arising from the use of corrosion-resistant materials for certain components.

14/01217 Ultimate strength assessment of corroded box girders

Saad-Eldeen, S. *et al. Ocean Engineering*, 2013, 58, 35–47.

This work deals with the evaluation of the ultimate bending moment of two box girders subjected to different levels of corrosion degradation and experimentally tested under pure vertical bending moment. A series of non-linear finite element analysis have been conducted. Two models of corrosion degradation have been used representing an average general corrosion thickness reduction, and the real corrosion thickness as it is measured. Based on the real corrosion measurements, experimental ultimate strength and finite element calculations, a relationship has been developed to predict the expected difference in the ultimate strength calculations based on the finite element models representing the corrosion degradation as an average thickness reduction or as the real measured corrosion reduction.

Fuel cell technology

14/01218 A generalized mathematical model to study gas transport in PEMFC porous media

Pant, L. M. *et al. International Journal of Heat and Mass Transfer*, 2013, 58, (1–2), 70–79.

A new mass transport model named modified binary friction model (MBFM) is proposed. The new mass transport model is based on the previously developed binary friction model (BFM) and is capable of predicting mass transport in viscous and transitional Knudsen regimes. Macro homogeneous mass transport models used in porous media are reviewed. The shortcomings of each model are discussed, and a comparison of the new mass transport model with existing models such as Fick's, dusty gas model and BFM is presented. It is found that the choice of transport model can significantly impact the predictions of mass transport. The transport predictions of the new model are significantly different compared to existing models for flow in Knudsen region and for mixtures containing gases with large difference in molecular weights.

14/01219 Breakthrough fuel cell technology using ceria-based multi-functional nanocomposites

Zhu, B. *et al. Applied Energy*, 2013, 106, 163–175.

Recent scientific and technological advancements have provided a wealth of new information about solid oxide-molten salt composite materials and multifunctional ceria-based nano-composites for advanced fuel cells (NANOCOFC). NANOCOFC is a new approach for designing and developing of multi-functionalities for nanocomposite materials, especially at 300–600 °C. NANOCOFC and low temperature advanced ceramic fuel cells (LTACFCs) are growing as a new promising area of research which can be explored in various ways. The ceria-based composite materials have been developed as competitive electrolyte candidates for low temperature ceramic fuel cells (LTCFCs). In the latest developments, multifunctional materials have been developed by integrating semiconductors and ion conductors, which have resulted in an emerging insight knowledge concerned with their R&D on single-component electrolyte-free fuel cells (EFFCs) – a breakthrough fuel cell technology. A homogenous component/layer of the semiconductors and ion conducting materials can realize fuel cell all functions to avoid using three components: anode, electrolyte and cathode, i.e. 'three in one' highlighted in an earlier paper. This report gives a short review and advance knowledge on worldwide activities on the ceria-based composites, emphasizing on the latest semi-ion conductive nanocomposites and applications for new applied energy technologies. It gives an overview to help the audience to get a comprehensive understanding on this new field.

14/01220 Comparative characterization of thermodynamic, electrical, and electrochemical properties of $Sm_{0.5}Sr_{0.5}Co_{1-x}Nb_xO_{3-\delta}$ ($x=0$, 0.05, and 0.1) as cathode materials in intermediate temperature solid oxide fuel cells

Yoo, S. *et al. Journal of Power Sources*, 2013, 226, 1–7.

The perovskite oxides, such as (La,Sr)CoO_3 and (Ba,Sr)CoO_3, have received much attention in recent years as cathode materials for intermediate temperature solid oxide fuel cells (IT-SOFCs). In this study, we have investigated the structural, electrical, electrochemical, and redox properties of $Sm_{0.5}Sr_{0.5}Co_{1-x}Nb_xO_{3-\delta}$ (SSCNbx) cathodes under conditions relevant to IT-SOFC operation. The SSCNbx (x = 0, 0.05 and 0.1) oxides show gradually decreasing electrical conductivity with increasing Nb doping at the same temperature. The maximum power density of SSCNbx (x = 0.05, 0.1) is lower than that of SSC; however, SSCNbx (x = 0.1) is more stable than SSC considering the thermodynamic behaviour, as determined through redox isotherms. These results suggest that an Nb doped SSC perovskite is suitable, considering its high power density and reasonable redox stability, as an IT-SOFC cathode material.

14/01221 Crosslinked sulfonated poly(arylene ether sulfone)/silica hybrid membranes for high temperature proton exchange membrane fuel cells

Chun, J. H. *et al. Renewable Energy*, 2013, 51, 22–28.

Sulfonated poly(arylene ether sulfone) copolymer is synthesized via nucleophilic step polymerization of sulfonated 4,4′-dichlorodiphenyl sulfone, 4,4′-dichlorodiphenyl sulfone and phenolphthalin monomers in the presence of potassium carbonate. The copolymer is blended with various amounts of silica particles to form organic–inorganic composite membranes. Esterification reaction is carried out between silica particles and the sulfonated polymer chains by thermal treatment in the presence of sodium hypophosphite, which catalysed the esterification reaction. The composition and incorporation of the sulfonated repeat unit are confirmed by ^1H NMR. The water uptake, proton conductivity, and thermal decomposition temperature of the membranes are measured. The silica content in the polymer matrix and the effect of esterification are evaluated. All composite membranes show better water uptake and proton conductivity than the unmodified membrane. Moreover, the membranes are tested in a commercial single cell at 80 and 120 °C in humidified H_2/air under different relative humidity conditions. The composite membrane containing 10% (w/w) silica shows the best performance among the prepared membranes especially under high temperature and low humidity conditions.

14/01222 Development of carbon fabric/graphite hybrid bipolar plate for PEMFC

Kim, K. H. *et al. Composite Structures*, 2013, 98, 103–110.

The bipolar plates have several functions in proton exchange membrane fuel cell (PEMFC); separating flow channels between gases, connecting electrical paths between cells in series and providing structural supports for the stack. Although the carbon fibre epoxy composite bipolar plates recently developed, have high specific stiffness and strength, they have relatively high electrical resistance compared to graphite bipolar plates due to their high surface electrical contact resistance, which requires additional surface treatment such as graphite layer coating. In this research, a new manufacturing method for the carbon fabric/graphite hybrid bipolar plate which consists of two carbon fibre fabrics and an expanded graphite foil liner between them, has been developed in order to increase the productivity of PEMFC and reduce its manufacturing cost by exposing bare carbon fabrics to decrease the surface electrical contact resistance of bipolar plate. Phenolic resin was chosen rather than epoxy resin for the matrix material to decrease both material cost and manufacturing time, and the optimum areal density of phenolic resin was determined experimentally. Also the corrosion resistance, electrical contact resistance and mechanical properties of the hybrid bipolar plates were measured.

14/01223 Electrochemical impedance spectroscopy as a diagnostic tool for the evaluation of flow field geometry in polymer electrolyte membrane fuel cells

Maidhily, M. *et al. Renewable Energy*, 2013, 51, 79–84.

In this study, two different designs of flow field have been evaluated by electrochemical impedance spectroscopy for polymer electrolyte membrane fuel cells. *Ex situ* experiments were conducted in serpentine and interdigitated flow field geometry. The authors have investigated the serpentine type flow field designs with varying rib and channel width geometry and studied their influence on the polymer electrolyte membrane fuel cell (PEMFC) performance. The anodic and cathodic resistances were also evaluated using symmetrical mode of operation. The three different types of multichannel serpentine geometry with 2, 1 and 0.7 mm rib and channel widths were used for evaluation and found that the mass transfer resistance was decreasing with rib and channel width thickness. The mass transfer resistance decreased by one order from 0.197 Ω for 2 mm channel width to 0.016 Ω for 0.7 mm channel width. The maximum power density obtained for PEMFC operating on H_2/Air at 50 °C, with 0.7, 1 and 2 mm rib and channel width was found to be 365, 291 and 202 mW/cm^2 respectively. This study emphasized the effect of rib and channel width geometry of flow fields by symmetrical mode of fuel cell operation using electrochemical impedance spectroscopy to obtain the anodic and cathodic mass transfer resistance individually.

14/01224 Improved performance of microbial fuel cells enriched with natural microbial inocula and treated by electrical current

Lin, H. *et al. Biomass and Bioenergy*, 2013, 54, 170–180.

Microbial fuel cells (MFCs) are increasingly attracting attention as a sustainable technology as they convert chemical energy in organic wastes to electricity. In this study, the effects of different inoculum sources (river sediment, activated sludge and anaerobic sludge) and electrical current stimulation were evaluated using single-chamber air-cathode MFCs as model reactors based on performance in enrichment process and electrochemical characteristics of the reactors. The result revealed the rapid anodic biofilm development and substrate utilization of the anaerobic sludge-inoculated MFC. It was also found that the river sediment-inoculated MFC achieved the highest power output of 195 μW, or 98 mW m^{-2}, due to better developed anodic biofilm confirmed by scanning electron microscopy. The current stimulation enhanced the anodic biofilm attachment over time, and therefore reduced the MFC internal resistance by 27%, increased the electrical capacitance by four folds, and improved the anodic biofilm resilience against substrate deprivation. For mature MFCs, a transient application of a negative voltage (−3 V) improved the cathode activity and maximum power output by 37%. This improvement was due to the bactericidal effect of the electrode potential higher than +1.5 V vs SHE, demonstrating a substantial benefit of treating MFC cathode after long-term operation using suitable direct electrical current.

14/01225 Investigation of species transport in a gas diffusion layer of a polymer electrolyte membrane fuel cell through two-phase modelling

Hossain, M. *et al. Renewable Energy*, 2013, 51, 404–418.

A two-phase polymer electrolyte membrane fuel cell model has been developed to investigate transport of species in a gas diffusion layer taking into account effects of liquid water saturation. A set of governing equations for mass, momentum, species concentration involving oxygen, hydrogen, water vapour and liquid water together with electrochemical reaction equations have been solved under computational fluid dynamics technique. The effects of presence of liquid water on the effective diffusivity of species have been investigated. A thorough comparison study of liquid water saturation model using power law with various exponential factors and a percolation based model has been carried out. The simulation results show that the power law model with exponential factor of two provides a good representation of species diffusivity and produces much closer agreement with experimental cell voltage, while the percolation based model produces overprediction of cell voltage. The effects of isotropic and anisotropic permeability of gas diffusion layer have also been studied and the simulated results show that the high isotropic permeability or a combination of high in-plane and low through-plane permeability results in higher performance of a polymer electrolyte membrane fuel cell. The fuel cell performance significantly deteriorates with low in-plane and high through-plane permeability of gas diffusion layer.

14/01226 Optimal sizing for UPS systems based on batteries and/or fuel cell

Vasallo, M. J. *et al. Applied Energy*, 2013, 105, 170–181.

Batteries in conventional fuel cell-based backup power systems carry out secondary tasks to support fuel cells in transient states. In this work, batteries fulfil an additional function: contributing to supply the load in stationary state, thus widening possibly the range of economical backup sizing solutions. Next, the sizing problem for this type of backup hybrid power systems is formulated in a generic way and discussed specifically when energy demand is given by an hourly load profile. A methodology was developed to solve this particular sizing problem by applying optimal control in energy management to reach optimal solutions. From a practical viewpoint, this methodology is used to size a backup power system for a telecommunication system. Several cases, based on realistic data, are studied with different parametric values. Hybrid solutions prove the best in a high number of cases.

14/01227 Optimization of PEM fuel cells for PV-hydrogen power system

Dokkar, B. *et al. Energy Procedia*, 2013, 36, 798–807.

This paper presents a photovoltaic–hydrogen power system for a mobile phone station. This base transceiver station (BTS) is located in an isolated location in the south of Algeria. The power system includes a photovoltaic (PV) field, water electrolyser and two fuel cells. Each fuel cell is used according to the daily and seasonal load of the station. A biphasic model is adopted for the simulation of fuel cell stacks. The governing equations are solved using a program written under Matlab. Multi-criteria optimization with weighting between two opposite objectives is used to determine the compromise solutions between maximum efficiency and minimal fuel cells size. A genetic algorithm coupled with the quasi-Newton method is used to achieve optimal fuel cells operations. The optimal solutions in the Pareto sense are plotted according to weighting coefficient. The obtained results show that number of PV modules for the summer period is relatively high (80 modules of 300 W), however there is a plan to use passive heating and new shelter material in order to reduce air conditioning loads. New equipment will also lead to reduced PV module requirements.

14/01228 Potential of SOFC CHP systems for energy-efficient commercial buildings

Naimaster IV, E. J. and Sleiti, A. K. *Energy and Buildings*, 2013, 61, 153–160.

An energy-efficient and low-emissions solid oxide fuel cell (SOFC) combined heat and power (CHP) system is a promising electric and thermal energy generation technology for implementation in future commercial buildings. Recently developed performance models for kW- and MW-sized SOFC CHP systems have been integrated into a building energy simulation model of a medium-sized (7000 m^2) office building to evaluate the potential of the system to lower annual utility costs and to reduce CO_2 emissions. An optimized 175 kW SOFC CHP system successfully lowered annual utility costs by up to 14.5% over a baseline HVAC system in locations with space heating-dominant loads. Potential CO_2 emissions were reduced by up to 62% over the baseline case for the optimized SOFC CHP systems. If the capital and installation costs of SOFC CHP systems are reduced in the near future, through the realization of cheaper, high-performance intermediate temperature SOFCs, the SOFC CHP system may be a promising energy-efficient and low-emitting alternative power and thermal energy cogeneration technology.

14/01229 Reduced model for the planar solid oxide fuel cell

He, Z. *et al. Computers & Chemical Engineering*, 2013, 52, 155–167.

Three-dimensional (3D) modelling for fuel cells is generally computationally expensive, especially for stacks. In order to reduce computational cost, spatial smoothing over the parallel plain channels in flow fields is introduced and applied to a 3D steady-state isothermal planar solid oxide fuel cell model, which is validated with experiment from literature. The 3D model is reduced to two-dimensional (2D) coupled with effective parameters and correlation factors, and then asymptotically reduced to parabolic partial differential equations and ordinary differential equations associated with space marching. The correlation factors, which are derived based on a full set of governing equations for electrokinetics over a cell cross-section, can handle not only variations in diffusion pathways due to ribs but also the coupling effect between governing equations. The reduced models are verified with the 3D counterpart in view of global and local properties. Good agreement with a quantitative loss of information is achieved. The reduction in computational cost is investigated.

14/01230 Simulation of a stand-alone residential PEMFC power system with sodium borohydride as hydrogen source

Pinto, P. J. R. *et al. International Journal of Electric Power & Energy Systems*, 2013, 49, 57–65.

Catalytic hydrolysis of sodium borohydride ($NaBH_4$) has been investigated as a method to generate hydrogen for fuel cell applications. The high purity of the generated hydrogen makes this process a potential source of hydrogen for polymer electrolyte membrane fuel cells (PEMFCs). In this paper, a PEMFC power system employing a $NaBH_4$ hydrogen generator is designed to supply continuous power to residential power applications as stand-alone loads and simulated using Matlab/Simulink software package. The overall system is sized to meet a real end-use load, representative of standard European domestic medium electric energy consumption, over a 1-week period. Supervisory control strategies are proposed to manage the hydrogen generation and storage, and the power flow. Simulation results show that the proposed supervisory control strategies are effective and the $NaBH_4$–PEMFC power system is a technologically feasible solution for stand-alone residential applications.

14/01231 Thermoeconomic analysis of large solid oxide fuel cell plants: atmospheric vs. pressurized performance

Gandiglio, M. *et al. Energy*, 2013, 55, 142–155.

A detailed thermoeconomic analysis of two large solid oxide fuel cell-based power plants operating at atmospheric pressure and 20 bar, respectively, is assessed in this work. The analysed systems employ SOFC-GT (gas turbine) modules as main power generators; a bottom heat recovery steam cycle to generate additional electricity from the SOFC-GT exhaust hot gases is also included. The thermodynamic and economic performance of the two plant configurations are studied in detail: the exergy analysis shows an enhanced exergetic performance for the pressurized cycle that features components with higher efficiency and consequently a lower rate of exergy destruction (~20% less than the atmospheric plant). The economic analysis considers the capital cost of each component within the system and is developed aiming at estimating the levelized cost of electricity. In order to match both exergetic and economic parts, a rigorous thermoeconomic analysis is implemented. A well-defined set of rules for the exergoeconomic balance around each plant component is specified and specific cost balance equations are thus derived. Results show how pressurized plant outperforms the atmospheric one, with a (on exergoeconomic base) cost of electricity of $47.7/MWh instead of $64.2/MWh. Therefore, both exergetic and economic advantages result from the adoption of a pressurized SOFC-GT cycle in the framework of future advance power plants based on high-temperature fuel cells.

15 ENVIRONMENT

Pollution, health protection, applications

14/01232 A comparative study among fossil fuel power plants in PJM and California ISO by DEA environmental assessment

Sueyoshi, T. and Goto, M. *Energy Economics*, 2013, 40, 130–145.

This study compares among fossil fuel power plants in Pennsylvania–New Jersey–Maryland (PJM) and California independent system operator (ISO) by their unified (operational and environmental) performance. Data envelopment analysis (DEA) is used as a methodology. For comparative analysis, DEA incorporates strategic concepts such as natural and managerial disposability into the computational process. This study explores both how to measure returns to scale (RTS) under natural disposability and how to measure damages to scale (DTS) under managerial disposability. This empirical study obtains two implications on US energy policy. One of the two policy implications is that California ISO outperforms PJM in terms of the three unified efficiency measures. The result implies that strict regulation on undesirable outputs, as found in California, is important in enhancing the performance of US fossil fuel power plants. Thus, it is necessary for federal and local governments to regulate the fossil fuel power plants under the strict implementation of environmental protection. Under such a policy direction, it is possible for US fossil fuel power plants to attain economic prosperity (by enhancing their operational efficiencies) and to satisfy environmental regulation (by enhancing their environmental efficiencies). The other policy implication is that coal-fired and gas-fired power plants in PJM and California ISO need to reduce their operational sizes or introduce technology innovation on desirable and undesirable outputs and/or new management for environmental protection within their operations. Meanwhile, oil-fired power plants may increase their operational sizes if they can introduce technology innovation and new management on undesirable outputs.

14/01233 A proposal to improve ecological compensation practice in road and railway projects in Spain

Villarroya, A. and Puig, J. *Environmental Impact Assessment Review*, 2013, 42, 87–94.

To reduce ecological impacts caused by development projects, avoidance, minimization and compensation techniques have to be taken together into consideration along environmental impact assessment (EIA) procedures. This paper explores the particular role that ecological compensation has had in recent road and railway EIA procedures in Spain, as seen through the review of a set of recent EIA records of decision that confirms precedent findings. Noticing that residual impacts are not paid much attention, and that there is no evidence of a solid public participation in ecological impact evaluation, it proposes to increase the awareness on residual impacts, as a way to make easier public access to the allegedly most sensitive moment of EIA implementation: (residual) impact evaluation.

14/01234 Assessment of the legislated particle number measurement procedure for a Euro 5 and a Euro 6 compliant diesel passenger cars under regulated and unregulated conditions

Mamakos, A. *et al. Journal of Aerosol Science*, 2013, 55, 31–47.

This study investigated the possibility of extending the legislated particle number (PN) measurement procedure to (a) control diesel exhaust emissions under unregulated driving conditions, including tests at −7 °C and during regeneration of the particulate filter, and (b) reduce the lowest detectable size below 23 nm, through dedicated tests of a Euro 5b and a Euro 6 diesel vehicles. The PN emissions of the two vehicles were at or below the limit of 6×10^{11} #/km under all non-regenerative conditions examined. Active regeneration of the diesel particulate filters (DPFs) occurred more frequently (220–510 km) than previously reported, and resulted in elevated particulate matter (up to 11 mg/km) and PN (1–4×10^{12} #/km) emissions. Condensation particle counters (CPCs) having a nominal 50% detection efficiency (10 nm and 4.5 nm) below the legislated 23 nm, detected 50–60% more non-volatile particles over the certification test cycle (new European driving cycle). Even higher excess fractions of nano-sized non-volatile particles (160–500%) were observed under urban driving of the Euro 5b vehicle at −7 °C, with the absolute levels still remaining below 6×10^{11} #/km, however. DPF regeneration and motorway driving favoured the homogeneous nucleation of volatile particles in the constant volume sampler, which also contributed to the signals of low cut-off size CPCs sampling downstream of the volatile particle remover. No evidence of such volatile interference could be observed in the legislated PN procedure. A potential shift of the lowest detectable size towards smaller sizes, will require further developments in the measurement procedure.

14/01235 Carbon and nutrients of Scots pine stands on sandy soils in Lithuania in relation to bioenergy sustainability

Armolaitis, K. *et al. Biomass and Bioenergy*, 2013, 54, 250–259.

Sustainable forestry is based on the principle that harvesting practices should avoid negative influence on soil fertility, wood production and long-term soil carbon (C) stocks. The authors examined C and nutrient concentrations and stocks of Scots pine (*Pinus sylvestris* L.) stands on *Arenosols* in south-western Lithuania. The stands were 10, 20, 40, 50 and 65 years of age. C concentrations were relatively constant, while the concentrations of N, P, K, Ca, Mg and S often varied between compartments and stand ages. The total aboveground stocks of nitrogen (N) were estimated to be in the range of 185–260 $\mathrm{kg\,ha^{-1}}$, and 78–189 $\mathrm{kg\,ha^{-1}}$ for calcium (Ca), 75–104 $\mathrm{kg\,ha^{-1}}$ for potassium (K), 22–33 $\mathrm{kg\,ha^{-1}}$ for phosphorus (P), 21–41 $\mathrm{kg\,ha^{-1}}$ for magnesium (Mg) and 16–28 $\mathrm{kg\,ha^{-1}}$ for sulfur (S). Corresponding stocks of the crown alone were 139–207 $\mathrm{kg\,ha^{-1}}$ of N, 54–88 $\mathrm{kg\,ha^{-1}}$ of Ca, 44–79 $\mathrm{kg\,ha^{-1}}$ of K, 15–26 $\mathrm{kg\,ha^{-1}}$ of P, 15–23 $\mathrm{kg\,ha^{-1}}$ of Mg, and 11–15 $\mathrm{kg\,ha^{-1}}$ of S. Biomass, C and nutrient stocks in the crown did not change with age, whereas the stemwood stocks increased with stand age. The total removals of C and N over a whole 100-year rotation were simulated to be 129 $\mathrm{Mg\,ha^{-1}}$ and 449 $\mathrm{kg\,ha^{-1}}$, respectively. An example scenario was created to compare the magnitude of potential nutrient removals with the atmospheric influx, soil stocks, and the internal litterfall flux. The authors suggest that intensified utilization of these stands for bioenergy may be sustainable.

14/01236 Design and characterization of small thermoelectric generators for environmental monitoring devices

Bonin, R. *et al. Energy Conversion and Management*, 2013, 73, 340–349.

A small thermoelectric generator to power autonomous sensors in remote environmental sites was studied, designed, realized, characterized, and tested. The thermoelectric phenomena, applied to the device, were theoretically introduced and experimentally verified by directly measuring the physical quantities when the thermoelectric generator operates in working conditions. The device was then tested under different external conditions, showing that it was able to supply, for sufficient time, an output voltage higher than 200 mV and an output power on the order of 10 mW when a temperature difference higher than 10 K and a load resistance close to the internal resistance are considered. Furthermore the authors developed a devoted power conditioning circuit in order to usefully manage the output voltage. Finally, the device was tested in real operative conditions.

14/01237 Ecosystem services in environmental assessment – help or hindrance?

Baker, J. *et al. Environmental Impact Assessment Review*, 2013, 40, 3–13.

This paper presents a critical analysis of the potential role of ecosystem services within environmental assessment, including both strategic environmental assessment and environmental impact assessment. It identifies some of the common problems with current environmental assessment practice and then explores whether integrating ecosystem services may be able to help address some of these problems. Case studies are included to illustrate different approaches to using ecosystem services within environmental assessment and to highlight how context (e.g. sector, scale and environmental situation) will influence the most appropriate way of integrating ecosystem services into environmental assessment practice. The analysis also reflects on how the potential role of ecosystem services may, or may not, differ from previous integrated approaches to environmental assessment and what lessons can be learnt from their development. Two main approaches are recognized from the literature and the case studies to integrating ecosystem services within environmental assessment. First, a comprehensive approach, where the assessment framework is entirely guided by ecosystem services; and second a philosophical approach that applies more of a light-touch ecosystems-thinking mind-set, helping to frame the assessment methodology rather than fundamentally defining it. Inevitably, there are variations between these two extremes, and benefits and criticisms of both. The authors conclude that ecosystem services provides a potentially valuable framing for environmental assessment, but that it requires a pragmatic, context specific consideration of how ecosystem services can be used to help address some of the common problems with current environmental assessment practice. There is also a need to recognize that at times it may just not be appropriate if it does not provide added value.

14/01238 Emission trading and international competition: the impact of labor market rigidity on technology adoption and output

Caparrós, A. *et al. Energy Policy*, 2013, 55, 36–43.

Emission trading systems have been proposed in different regions to reduce polluting emissions and are in use in the European Union for carbon dioxide emissions. One of the objectives of these systems is to encourage firms to adopt advanced abatement technologies. However, permits also create an incentive to reduce output, which may be seen as negative by policy makers. The authors analyse the impact of a rigid labour market on these two outcomes, showing the conditions necessary to avoid reductions in production while keeping the incentives to improve abatement technologies. The analysis is done for oligopolistic firms engaged in international rivalry.

14/01239 Market power, private information, and the optimal scale of pollution permit markets with application to North Carolina's Neuse River

Yates, A. J. *et al. Resource and Energy Economics*, 2013, 35, (3), 256–276.

This study extends the analysis of optimal scale in pollution permit markets by allowing for both market power and private information. The authors characterize the total costs (abatement costs and damages) under market power and private information and compare them to total costs under competition. It is possible for both market power and private information to lead to lower total costs than competition, but generally the differences between the three market structures will be small. The authors also conduct an optimal scale analysis of nitrogen pollution from waste water treatment plants (WWTP) into North Carolina's Neuse River System. An economic model of damages and abatement costs is integrated with a hydro-ecological model of nitrogen flow through the Neuse. They determine the optimal number of trading zones and allocate the WWTP into these zones. Under the most likely regulatory scenario, cost savings of $1.55 million per year were found under the optimal market design relative to the typical 303(d) regulation in which the WWTP are not allowed to trade.

14/01240 Occupancy-based zone-climate control for energy-efficient buildings: complexity vs. performance

Goyal, S. *et al. Applied Energy*, 2013, 106, 209–221.

This study proposes several control algorithms and compare their performance and complexity through simulations; the control algorithms regulate the indoor climate of commercial buildings. The goal of these control algorithms is to use occupancy information to reduce energy use – over conventional control algorithms – while maintaining thermal comfort and indoor air quality. Three novel control algorithms are proposed, one that uses feedback from occupancy and temperature sensors, while the other two compute optimal control actions based on predictions of a dynamic model to reduce energy use. Both the optimal control based schemes use a model predictive control (MPC) methodology; the difference between the two is that one is allowed occupancy measurements while the other is allowed occupancy predictions. Simulation results show that each of the proposed controllers lead to significant amount of energy savings over a baseline conventional controller without sacrificing occupant health and comfort. Another key finding is that the feedback controller performs almost as well as the more complex MPC-based controllers. In light of the complexity of the MPC algorithms compared to the feedback control algorithm, the authors conclude that feedback control is the more suitable one for occupancy based zone-climate control. A related conclusion is that the difficulty of obtaining occupancy predictions does not commensurate with the resulting benefits; though these benefits are a strong function of ventilation standards.

14/01241 Reduction of CO_2 emission by improving energy use efficiency of greenhouse cucumber production using DEA approach

Khoshnevisan, B. *et al. Energy*, 2013, 55, 676–682.

The main purpose of this study was to determine energy use efficiency in greenhouse cucumber production using a non-parametric production function. Energy use efficiency of greenhouse cucumber producers was studied and degrees of technical efficiency, pure technical efficiency and scale efficiency were determined using data envelopment analysis (DEA). Additionally, wasteful uses of energy inputs were assessed and energy saving from different sources was computed. Furthermore, the effect of energy optimization on CO_2 emission as one of the major greenhouse gases was investigated and total amount of CO_2 emission was calculated. Average of total input and output energies were calculated as 1,667,164.8 and 151,846.2 MJ ha^{-1}. Energy use pattern indicated that natural gas and electricity were the main energy inputs. Based on the results 24.46% (407,916.3 MJ ha^{-1}) of overall energy resources can be saved if the performance of inefficient farms is enhanced. Additionally, the total CO_2 emission was calculated as 45,177.3 kg CO_{2eq} ha^{-1}. Finally it was concluded that, by energy optimization the total energy consumption can be reduced to the value of 1,259,248 MJ ha^{-1} and correspondingly the total CO_2 emission is reduced to value of 34,995.9 kg CO_{2eq} ha^{-1}.

14/01242 Review of structural health and cure monitoring techniques for large wind turbine blades

Schubel, P. J. *et al. Renewable Energy*, 2013, 51, 113–123.

A review of structural health monitoring methods, including residual cure strain monitoring is presented for the wind turbine blade industry. A comparison is presented for dielectric, acoustic, ultrasonic, thermal and fibre optic monitoring methods. This review highlights the need for further development in this area, with potential savings to manufacturing time and reductions in cost through quality control measures, including furthering the scientific understanding of cure strain, are just some of the downstream benefits. Upstream benefits include increased investor confidence through better design, manufacture and operational practices.

14/01243 The impact of water depth on safety and environmental performance in offshore oil and gas production

Muehlenbachs, L. *et al. Energy Policy*, 2013, 55, 699–705.

This paper reports on an empirical analysis of company-reported incidents on oil and gas production platforms in the Gulf of Mexico between 1996 and 2010. During these years, there was a dramatic increase in the water depths at which offshore oil and gas is extracted. Controlling for platform characteristics such as age, quantity of oil and gas produced, and number of producing wells, it was found that incidents (such as blowouts, injuries, and oil spills) are positively correlated with deeper water. Controlling for these and other characteristics, for an average platform, each 100 feet of added depth increases the probability of a company-reported incident by 8.5%. While further research into the causal connections between water depth and platform risks is warranted, this study highlights the potential value of increased monitoring of deeper water platforms.

14/01244 The relevance of environmental conflict research for coastal management. A review of concepts, approaches and methods with a focus on Europe

Stepanova, O. and Bruckmeier, K. *Ocean & Coastal Management*, 2013, 75, 20–32.

Analysis and resolution of coastal resource use conflicts have largely been neglected in coastal research, environmental policies and resource management strategies such as integrated coastal zone management. The authors review theoretical approaches and empirical studies from European countries about environmental and natural resource use conflicts with the aim to clarify the requirements for developing interdisciplinary coastal conflict research as a component of sustainable coastal management. Issues of terminology, conceptual and methodological differences and requirements for analysing and solving resource use and management conflicts are addressed. Thereafter, possibilities of consolidation of the research field and the perspectives of future coastal conflict research are discussed – along with comparative studies of conflicts, conflict management, and integration of the knowledge of resource users. It is concluded that the reviewed conflict concepts, typologies and approaches can be integrated and thus help to improve context-specific analysis of multi-scale coastal conflicts. Such conflicts are part of sustainable resource management that needs to deal with consequences of global environmental change, especially the rise in sea levels in coastal areas.

14/01245 When is a 'wait and see' approach to invasive species justified?

Sims, C. and Finnoff, D. *Resource and Energy Economics*, 2013, 35, (3), 235–255.

Predictions of damages and damages that might be avoided from invasive species control policies are marred by uncertainty that has both economic and ecological roots. Public policies directed at invasive species typically lag their detection. One possible explanation is the coupling of uncertainty with political and economic commitments creates an incentive to delay a policy response in order to gain more information on how damaging the invasion will be – a 'wait and see' approach. The authors investigated whether this rationale was justified by identifying invasion characteristics that require the wait and see approach often adopted by lawmakers and government agencies. The model shows that the source of uncertainty and degree of policy irreversibility matter and allows the classification of invasive species with a low rate of spread and low levels of uncertainty as those where policies can be optimally timed in the future.

CO_2, NO_x, SO_2 and particulate emissions

14/01246 A review of research progress on CO_2 capture, storage, and utilization in Chinese Academy of Sciences

Li, L. *et al. Fuel*, 2013, 108, 112–130.

This article reviews the progress made in CO_2 capture, storage, and utilization in Chinese Academy of Sciences. New concepts such as adsorption using dry regenerable solid sorbents as well as functional ionic liquids for CO_2 capture are thoroughly discussed. Carbon sequestration, such as geological sequestration, mineral carbonation and ocean storage are also covered. The utilization of CO_2 as a raw material in the synthesis of chemicals and liquid energy carriers which offers a way to mitigate the increasing CO_2 build-up is introduced.

14/01247 Assessment test of sulfur content of gases

Eslamimanesh, A. *et al. Fuel Processing Technology*, 2013, 110, 133–140.

The experimental sulfur content data of various gases are evaluated in this work for outlier diagnostics. The leverage statistical algorithm is applied for this purpose, which includes determination of the statistical Hat matrix, sketching the Williams plot, and calculation of the residuals of selected correlation results. Moreover, the applicability domains of the employed correlation and the quality of the existing experimental data are checked along with the outlier detection. The previously proposed del Valle and Aguilera correlation is applied for representation/prediction of the sulfur content of several gas samples. It is found that the applied correlation for representation of the corresponding solubilities is statistically valid and correct, three data points are not within its applicability domain and one datum is a probable outlier of the evaluated datasets.

14/01248 Capturing atmospheric CO_2 using supported amine sorbents for microalgae cultivation

Brilman, W. *et al. Biomass and Bioenergy*, 2013, 53, 39–47.

This study proposes, demonstrates and evaluates the concept of atmospheric CO_2 capture for enhanced algae cultivation (and horticulture), as an alternative to the application of flue-gas derived CO_2. A supported amine sorbent was prepared which able to capture CO_2 at atmospheric conditions and releasing it at higher pressures and purity. Adsorption capacities were determined for CO_2 concentrations from $\phi_{CO_2} = 0.0200\%$ to 10% and temperatures up to 55 °C. Regeneration was done by thermal swing. At high temperatures (above 100 °C) high purity CO_2 can be produced at elevated pressure. However, this is not required for algae cultivation and regeneration at lower purity (e.g. $\phi_{CO_2} = 2\%$) allows for lowering the regeneration temperature down to 70–80 °C, enabling the use of low grade heat. Under these conditions the sorbent is still able to realize cyclic capacities for CO_2 of around $2\,\mathrm{mol\,kg^{-1}}$ sorbent. In cultivation experiments the effect of CO_2 dosing on the growth rate of *Desmodesmus* sp. was investigated, showing an optimum at $\phi_{CO_2} = 1.5\%$. Experiments were carried out adsorbing CO_2 from air, producing a CO_2 enriched gas and use this in the cultivation of *Desmodesmus* sp., thereby successfully demonstrating the concept. Finally, the concept is compared with CO_2 dosing using fossil fuel derived flue gas. Energy costs are comparable and additional benefits, as flexibility with respect to location and scale, avoiding impurities and, above all, closing the carbon cycle makes atmospheric CO_2 capture a competitive, sustainable option for algae biorefineries.

14/01249 Carbon dioxide emissions and governance: a nonparametric analysis for the G-20

Halkos, G. E. and Tzeremes, N. G. *Energy Economics*, 2013, 40, 110–118.

This paper applies nonparametric estimators to examine the carbon dioxide emissions–governance relationship. By using data for the 20 largest economies (group of 20 countries, G-20) the dynamics of the considered relationship are analysed for the time period 1996–2010. Six governance measures are included in the analysis (voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption) as have been defined by the World Bank. The empirical findings reveal a high non-linear relationship between countries' carbon dioxide emissions and the examined governance measures. The results reveal significant differences on the number of governance measures influencing countries' carbon dioxide emission levels. It is evident that these differences are subject to countries' specific regional and development variations. Finally, it appears that increasing the quality of countries' different governance factors does not always result to lower carbon dioxide emission levels.

14/01250 Carbon dioxide in the urban area of Naples: contribution and effects of the volcanic source

Granieri, D. *et al. Journal of Volcanology and Geothermal Research*, 2013, 260, 52–61.

Naples is a large Italian city located between two active volcanic areas: Campi Flegrei to the west and Vesuvius to the south-east. The Solfatara crater, inside the caldera of the Campi Flegrei and nearest to the western quarters of the city, is a prodigious source of natural CO_2 with a mean emission rate of 1067 ton/day, i.e. seven times higher than that of Vesuvius (151 ton/day). This study shows that the area around the Solfatara and part of the urban area of Naples are affected by the volcanic plume when atmospheric circulatory patterns are dominated by the locally frequent sea breezes. Under these conditions the CO_2 content in the air increases above normal values, reaching more than 1000 ppm in proximity to the Solfatara crater to a few tens of ppm several kilometres from the source. Although these values do not indicate a health risk even under the most unfavourable atmospheric conditions, the volcanic source contributes to the total CO_2 burden from all urban emissions and hence to overall air quality. An emission rate 10 times higher than the present one would lead to an air CO_2 concentration in excess of recommended health protection thresholds.

14/01251 Comparative study of computational intelligence approaches for NO_x reduction of coal-fired boiler

Wei, Z. *et al. Energy*, 2013, 55, 683–692.

This paper focuses on NO_x emission prediction and operating parameters optimization for coal-fired boilers. A support vector regression (SVR) model based on a conventional genetic algorithm (CGA) was proposed to model the relationship between the operating parameters and the concentration of NO_x emission. Then CGA and two modified algorithms, the quantum genetic algorithm (QGA) and the simulated annealing genetic algorithm (SAGA), were employed to optimize the operating parameters of the coal-fired boiler to reduce NO_x emission. The results showed that the proposed SVR model was more accurate than the widely used artificial neural network model when employed to predict the concentration of NO_x emission. The mean relative error and correlation coefficient calculated by the proposed SVR model were 2.08% and 0.95, respectively. Among the three optimization algorithms implemented in this paper, the SAGA showed superiority to the other two algorithms considering the quality of solution within a given computing time. The SVR plus SAGA method was preferable to predict the concentration of NO_x emission and further to optimize the operating parameters to achieve low NO_x emission for coal-fired boilers.

14/01252 Dissolution rates of alkaline rocks by carbonic acid: influence of solid/liquid ratio, temperature, and CO_2 pressure

Abe, Y. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 933–941.

Dissolution rates of alkaline rocks, including wollastonite ($CaSiO_3$), olivine (Mg_2SiO_4), and phlogopite ($KMg_3AlSi_3O_{10}(OH)_2$), with high pressure aqueous CO_2 solution were measured to examine the feasibility of CO_2 fixation via carbonation. Influence of solid/liquid ratio (1.0–10 g/250 mL), temperature (303–353 K), and CO_2 pressure (1.0–3.0 MPa) on the extraction rates of calcium or magnesium ions was investigated. Under the experimental conditions studied, the calcium ion extraction rate from wollastonite was the highest among the three rock samples studied. The calcium concentration reached about 120 mg/L, and about 12% of the calcium in wollastonite sample was extracted after 60 min at 353 K with 1.0 MPa CO_2. The calcium and magnesium extraction ratios from the alkaline rocks were much lower than those from waste concrete powder. Increasing the extraction time and temperature would be an effective way to promote calcium extraction from wollastonite.

14/01253 Dynamic modelling of the absorber of a post-combustion CO_2 capture plant: modelling and simulations

Jayarathna, S. A. *et al. Computers & Chemical Engineering*, 2013, 53, 178–189.

Modelling work related to carbon dioxide (CO_2) capture technologies is of great importance with respect to the design, control, and optimization of the capture process. Development of dynamic models as such is important since there is much information embedded with the dynamics of a plant which cannot be studied with steady state models. A model for the absorption column of a post-combustion CO_2 capture plant is developed following the rate based approach to represent heat and mass transfer. The Kent–Eisenberg model is used to compute the transfer and generation rates of the species. Sensitivity of the model for different physiochemical property correlations is analysed. The predictions of the dynamic model for the capture plant start-up scenario and operation of the absorption column under varying operating conditions in the up-stream power plant and the down-stream stripping column are presented. Predictions of the transient behaviour of the developed absorber model appear realistic and comply with standard steady state models.

14/01254 Emissions of particles and trace elements from coal gasification

Yoshiie, R. *et al. Fuel*, 2013, 108, 67–72.

Some of the trace elements in coal are easily emitted with the syngas obtained from coal gasification in the gaseous phase and condensed as fine particles. Such impurities in syngas could result in corrosion and/or degradation of electrode materials in fuel cells if the coal gasification process is applied to integrated gasification fuel cells (IGFC). Thus, to realize the coal gasification process combined with fuel cells, it is extremely important to control the emission behaviour of hazardous trace elements in coal gasification. In this study, particles in the coal gasification gas were sampled and analysed in detail to determine their particle size distributions and elemental compositions. A drop tube type furnace was utilized for the coal gasification experiment. Pb and Se were evaluated in terms of their distribution behaviour to particles. Pb is one of the most typical volatile heavy metals, and Se is known as a corrosive substance for solid oxide fuel cells. Thermal equilibrium calculations were also conducted to derive the chemical forms of Pb and Se during their emissions. As a result, particles entrained in syngas from the coal gasification process were confirmed to have bimodal peaks in their particle size distributions. The peak larger than 7.8 µm in the super-micron size range consists of ash with unburnt carbon, while the smaller peak at 0.5 µm in the sub-micron range consists of soot with mineral deposits. Se and Pb were found to react together during coal gasification process. In addition, almost all of them were vaporized in the reactor and deposited on soot particles in the sub-micron range during the gas cooling process.

14/01255 Multi-step-ahead prediction of NO_x emissions for a coal-based boiler

Smrekar, J. *et al. Applied Energy*, 2013, 106, 89–99.

From 2016, power plants within the European Union (EU) will have to meet new limits on emissions as dictated by EU regulations. One of the major challenges is to reduce emissions of nitrogen oxides (NO_x) due to health and ozone-formation concerns. Combustion optimization is one of the primary measures for reducing NO_x emissions from boilers burning coal, oil or natural gas. The optimization can be achieved by excess air control, boiler fine tuning and balancing the fuel and air flow to the various burners in order to reach minimum NO_x formation. In this paper, a multi-step-ahead prediction of NO_x emissions that can provide a basis for on-line control is presented. About 9 days' worth of real data were acquired from an operator of a coal-based power plant for this study. It begins with a presentation of measured variables, pre-processing of the data and a definition of performance measures. Feature selection analysis follows, identifying the variables important for multi-step NO_x prediction. In this respect, the impact of primary variables that are directly related to the combustion process is compared against that of other variables important in boiler operation and some transformed variables. Based on optimal features, a model comparison study including linear (ARX and ARMAX) and non-linear (NN and SVR) modelling approaches is presented. Results of the model comparison study reveal that for the analysed boiler, non-linear models do not improve the robust prediction performance of a linear ARX model. In the last part of the paper, an adaptive modelling approach further investigates the potential improvements in NO_x prediction. A comparison of static and adaptive versions of the linear ARX model reveals that the adaptive approach does not improve prediction performance significantly. Hence the static ARX model in combination with an optimally selected set of input variables and extracted features is recommended for the multi-step NO_x prediction of the coal-based boiler.

14/01256 Performance assessment of producing $Mg(OH)_2$ for CO_2 mineral sequestration

Nduagu, E. *et al. Applied Energy*, 2013, 106, 116–126.

This study presents the energy and environmental performance assessment of producing magnesium hydroxide ($Mg(OH)_2$) from Mg–silicates for CO_2 mineral sequestration applied to a natural gas combined cycle (NGCC) power plant. $Mg(OH)_2$ produced via a closed loop reaction of serpentinite and ammonium sulfate (AS), precipitation of $Mg(OH)_2$ and AS looping/recovery binds CO_2 into a thermodynamically stable, environmentally benign and leak-free magnesium carbonate ($MgCO_3$). The authors used results from laboratory, modelling and life cycle assessment (LCA) studies to determine the extent to which magnesium (Mg) from serpentinite rock can be converted to $Mg(OH)_2$, the effects of reaction parameters, scalability and the associated life cycle greenhouse gas (GHG) emissions. The authors found that reaction temperature positively affects Mg extraction from serpentinite, reaching a maximum yield at different temperatures depending on the reaction time. Also, the reactor properties affect the extraction results as the optimal extraction yield and conditions reported for different reactors differ. While the process of producing $Mg(OH)_2$ is promising, it also possesses a level of energy and environmental burden that cannot be ignored when considering large-scale implementation. At 100% conversion and recovery of reagent, the CO_2 mineralization process has a life cycle global warming potential (GWP) of 433 kg CO_2 equivalents per ton CO_2 (CO_2e/t-CO_2). This value increases by 82, 7 and 0.4 kg CO_2e/t-CO_2 for every %-point efficiency loss of AS recovery, $Mg(OH)_2$ production and $Mg(OH)_2$ carbonation respectively. Mineral sequestration applied to the 555 MW NGCC plant reduces its net plant efficiency from 50.2% to 38.6%-points (an energy penalty of 30%) but avoids 51% of the GHG emissions to the atmosphere. The results from this study are timely, and could have significant implications on mineral sequestration methods that consider the exothermic nature of the overall mineral carbonation chemistry beneficial.

14/01257 Temporal and spatial trends of residential energy consumption and air pollutant emissions in China

Zhu, D. *et al. Applied Energy*, 2013, 106, 17–24.

Residential energy consumptions of both electricity and fuels are associated with emissions of many air pollutants. Temporally and spatially resolved energy consumption data are scarce in China, which are critical for a better understanding of their environmental impacts. In this study, a space-for-time substitution method was proposed and two models for predicting fuel and electricity consumptions in residential sector of China were developed using provincial data. It was found that fuel consumption was not directly proportional to heating degree day and was also affected by heating day, defined as the number of days when heating is required in a year. The models were validated against a set of historical annual data and two sets of survey data on seasonal variations. The models were applied to predict spatial and temporal variations of residential energy consumptions and emissions of various pollutants and to predict net effects of climate warming on energy consumptions and pollutant emissions. The emissions of black carbon (BC), carbon monoxide (CO), and polycyclic aromatic carbons (PAHs) in winter were significantly higher than those in other seasons. For the emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x), there were two peaks in winter and summer, with the latter increasing gradually over years. It was predicted that per-capita residential energy consumptions would reach 0.43, 0.33, and 0.26 toe/cap in 2050 for IPCC scenarios of A1B, B1, and A2, respectively. Climate warming in the future would lead to less residential fuel but more electricity consumptions. Consequently, emissions of BC, CO, and PAHs would decrease mainly in cold climate zones, while emissions of CO_2, SO_2, and NO_x would increase largely in south-east China.

14/01258 The northernmost Adriatic Sea: a potential location for CO_2 geological storage?

Donda, F. *et al. Marine and Petroleum Geology*, 2013, 42, 148–159.

In 2009, the Italian National Institute of Oceanography and Experimental Geophysics (OGS) performed a geophysical survey in the northernmost sector of the northern Adriatic Sea, between the Tagliamento and Po river deltas, with R/V OGS *Explora*. About 820 km of two-dimensional multichannel seismic and Chirp profiles, together with multibeam data along the ship tracks, have been acquired, with the aim to reconstructing the Plio-Quaternary stratigraphic and tectonic setting of the study area. Data have been also analysed to verify whether this region is suitable for CO_2 geological storage. Sites eligible for the application of carbon capture and storage techniques have been already identified in the Adriatic Sea, except in the northernmost sector, due to the scarcity of available data. The analyses of the new OGS seismic dataset highlighted the occurrence of peculiar seismic anomalies, represented by sub-vertical wipe-out zones, that have been interpreted as due to gas leakages affecting the Plio-Quaternary sequence. They could be possibly related to the formation of rock outcrops interpreted as methane-derived carbonates. It is suggested that gas migrates along sub-vertical chimneys throughout the Plio-Quaternary sequence. The correlation of these sub-vertical features among the seismic profiles reveals that two main alignments could be recognized: a NW–SE trend offshore the Venice Lagoon and a NE–SW in the northernmost part of the investigated area. It leads to hypothesize that the preferential conduits for gas migration are associated to tectonic lineaments. The analysis of the tectonic setting has been then addressed at defining the role of fault/fracture zones, which can affect the integrity of a CO_2 storage complex in this area. Tectonic features have been identified in the Mesozoic–Paleogene succession, but their relationship with the shallow faults/fractures representing the paths for gas leakages still need further work and additional data in order to be clearly constrained.

14/01259 The optimal lifetime of passenger cars based on minimization of CO_2 emission

Mijailović, R. *Energy*, 2013, 55, 869–878.

The paper's objective is to suggest a model for determining optimal lifetime of passenger car based on the minimization of CO_2 emissions. The life cycle was modelled by eight main life cycle sequences. Combining the mathematical interpretations of the itch life cycle sequence is developed an optimization model. In this paper is suggested a new mathematical interpretation of following sequences: use, repair, distribution of passenger car and distribution of passenger car's parts. Comparison of the obtained numerical results was performed on examples for the data of new passenger car fleet from 14 European Union countries. Special attention is given to analysis of dependencies between the optimal lifetime of passenger cars and Directive 2000/53/EC, trends of changing car weight, model year, kilometre driven and regulatory limit of the specific CO_2 emission. The optimal lifetime in case where petrol car is replaced by diesel car was analysed as well.

Hydrocarbon emissions

14/01260 Values of the mass transfer coefficient of the linear driving force model for VOC adsorption on activated carbons

Chauveau, R. *et al. Chemical Engineering Research and Design*, 2013, 91, (5), 955–962.

It is important to model activated carbon cartridges in order to know the duration of protection of personal protective equipment used against toxic gases. The linear driving force (LDF) model seems to be more adapted than the actual Wheeler–Jonas model because it has more physical significance. Globally the LDF model gives a correct representation of the fronts. The LDF mass transfer coefficient has been calculated from experimental breakthrough fronts of the two compounds at several concentrations. Obtained values are about constant over a large range of concentrations 250–2000 ppm. Mean values are 0.122 and 0.176 min^{-1} for methyl acetate and vinyl chloride, respectively. The value increases at lower concentrations especially for vinyl chloride.

Life cycle analysis

14/01261 Life cycle assessment of biodiesel production in China

Liang, S. *et al. Bioresource Technology*, 2013, 129, 72–77.

This study aims to evaluate energy, economic, and environmental performances of seven categories of biodiesel feedstocks by using the mixed-unit input–output life cycle assessment method. Various feedstocks have different environmental performances, indicating potential environmental problem-shift. Jatropha seed, castor seed, waste cooking oil, and waste extraction oil are preferred feedstocks for biodiesel production in the short term. Positive net energy yields and positive net economic benefits of biodiesel from these four feedstocks are 2.3–52.0% of their life cycle energy demands and 74.1–448.4% of their economic costs, respectively. Algae are preferred in the long term mainly due to their less arable land demands. Special attention should be paid to potential environmental problems accompanying feedstock choice: freshwater use, ecotoxicity potentials, photochemical oxidation potential, acidification potential and eutrophication potential. Moreover, key processes are identified by sensitivity analysis to direct future technology improvements. Finally, supporting measures are proposed to optimize China's biodiesel development.

14/01262 Life cycle assessment of biofuel production from brown seaweed in Nordic conditions

Alvarado-Morales, M. *et al. Bioresource Technology*, 2013, 129, 92–99.

The use of algae for biofuel production is expected to play an important role in securing energy supply in the next decades. A consequential life cycle assessment (LCA) and an energy analysis of seaweed-based biofuel production were carried out in Nordic conditions to document and improve the sustainability of the process. Two scenarios were analysed for the brown seaweed (*Laminaria digitata*), namely, biogas production (scenario 1) and bioethanol + biogas production (scenario 2). Potential environmental impact categories under investigation were global warming, acidification and terrestrial eutrophication. The production of seaweed was identified to be the most energy intensive step. Scenario 1 showed better performance compared to scenario 2 for all impact categories, partly because of the energy intensive bioethanol separation process and the consequently lower overall efficiency of the system. For improved environmental performance, focus should be on optimization of seaweed production, bioethanol distillation, and management of digestate on land.

14/01263 Life cycle assessment of experimental cubicles including PCM manufactured from natural resources (esters): a theoretical study

Menoufi, K. *et al. Renewable Energy*, 2013, 51, 398–403.

Among the research activities that aim at reducing energy consumption in buildings and their impact on the environment is an experimental set-up that has several house-shaped cubicles constructed in Puigverd de Lleida, Spain. Assessing the environmental impact through studying the manufacturing, operational and disposal phases of these cubicles have been done in previous research. The objective of this paper is to investigate the use of esters as phase change materials (PCM) in order to estimate its environmental impact in building envelopes in comparison to the use of paraffin or salt hydrates through a theoretical study. The evaluation of the environmental impact of this type of PCM material is conducted using life cycle assessment based on the Eco-indicator 99 method. It is found that the impact of ester used as PCM presents slightly better results than the case of using salt hydrates during the manufacturing impact. On the other hand, the use of salt hydrates or esters as PCM in the cubicles results in an impact reduction of 9% and 10.5% respectively, compared to the case of using paraffin.

14/01264 Life cycle assessment of greenhouse gas emissions of feedlot manure management practices: land application versus gasification

Wu, H. *et al. Biomass and Bioenergy*, 2013, 54, 260–266.

Animal waste is an important source of anthropogenic greenhouse gas (GHG) emissions, and in most cases, manure is managed by land application. Nevertheless, due to the huge amounts of manure produced annually, alternative manure management practices have been proposed, one of which is gasification, aimed to convert manure into clean energy-syngas. Syngas can be utilized to provide energy or power. At the same time, the byproduct of gasification, biochar, can be transported back to fields as a soil amendment. Environmental impacts are crucial in selecting the appropriate manure strategy. Therefore, GHG emissions during manure management systems (land application and gasification) were evaluated and compared by life cycle assessment (LCA) in this study. LCA is a universally accepted tool to determine GHG emissions associated with every stage of a system. Results showed that the net GHG emissions in land application scenario and gasification scenario were 119 and −643 kg CO_2-eq for one tonne of dry feedlot manure, respectively. Moreover, sensitive factors in the gasification scenario were efficiency of the biomass integrated gasification combined cycle (BIGCC) system and energy source of avoided electricity generation. Overall, due to the environmental effects of syngas and biochar, gasification of feedlot manure is a much more promising technique as a way to reduce GHG emissions than is land application.

14/01265 Life cycle assessment of the air emissions during building construction process: a case study in Hong Kong

Zhang, X. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 160–169.

The generation of a significant amount of emissions from buildings construction has led the promotion of controlling emissions as an important strategy for implementing sustainable development principles in the built environment. The emissions incurred during various stages include carbon dioxide, methane, nitrous oxide, sulfur dioxide, carbon monoxide, nitrogen oxide, non-methane volatile organic compounds and particulate matter. This paper conducts a life cycle assessment of the air emissions by using a particular case to examine emissions during the construction stage. This study examines the emissions sources in each of the six stages and presents an inventory analysis method to measure air emissions to quantify the air emissions during the six life cycle stages for buildings. This method can help evaluating the impacts of implementing a building on air quality, thus actions can be taken in early stages to reduce the environmental impacts during building life cycle. A case study is presented to demonstrate the practical application of the method with reference to the building practices for all life cycle stages in Hong Kong.

14/01266 Life cycle carbon dioxide assessment tool for buildings in the schematic design phase

Baek, C. *et al. Energy and Buildings*, 2013, 61, 275–287.

The existing assessment tools for the life cycle carbon dioxide ($LCCO_2$) have certain limitations in that users have to directly enter quantities of materials after the construction document phase and they are likely to find it difficult to formulate an optimal strategy to reduce CO_2 emissions. Therefore, Global Environmental Model/Management-21P (GEM-21P) was developed for establishing a responsive and accurate system for suggesting methods for high-energy efficiency in the planning phase. The objective of this study was to identify the requisites for an $LCCO_2$ assessment programme that is based on the technical elements of GEM-21P and that can be used in the schematic design phase. The life cycle of a building is divided into four stages: material production, construction, operation, and dismantlement/disposal. Further, the technical elements of GEM-21P are examined for assessing CO_2 emissions in each of the stages. On the basis of the examination results, the authors specify the requisites for a system that can assess, in the planning phase, the CO_2 emitted from a building during its entire life.

14/01267 Sustainable design and synthesis of hydrocarbon biorefinery via gasification pathway: integrated life cycle assessment and technoeconomic analysis with multiobjective superstructure optimization

Wang, B. *et al. Computers & Chemical Engineering*, 2013, 52, 55–76.
This paper proposes a multiobjective, mixed-integer non-linear programming (MINLP) model for the superstructure optimization of hydrocarbon biorefineries via gasification pathway under economic and environmental criteria. The proposed hydrocarbon biorefinery superstructure includes a number of major processing stages, such as drying of the cellulosic biomass feedstocks, air separation unit, gasification, syngas conditioning, Fischer–Tropsch synthesis, hydroprocessing, power generation, and the diesel and gasoline production. The superstructure considers alternatives of technologies and equipment, such as gasification technologies, cooling options, hydrogen production sources, and Fischer–Tropsch synthesis catalysts. The economic objective is measured by the net present value (NPV), and the environmental concern is measured using global warming potential (GWP) that follows the life cycle assessment procedures, which evaluates the gate-to-gate environmental impacts of hydrocarbon biofuels. The multiobjective MINLP model simultaneously determines the technology selection, operation conditions, flow rate of each stream, energy consumption of each unit, economic performance, environmental impacts, and equipment sizes. The multiobjective MINLP problem is solved with the ϵ-constraint method. The resulting Pareto-optimal curve reveals the trade-off between the economic and environmental performances. The optimal solution reveals that the high-temperature gasification, direct cooling, internal hydrogen production and cobalt catalysis have the best environmental and economic performances. At the breakeven point, where the optimal NPV is 0, the unit production cost of hydrocarbon biorefinery is $4.43 per gasoline-equivalent gallon (GEG) with unit GWP of 20.92 kg CO_2 eqv./GEG. In the case of maximum NPV of $810 MM, the corresponding unit production cost is $3.17/GEG.

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Supplies, policy, economics, forecasts

14/01268 A review of clean energy innovation and technology transfer in China

Liu, H. and Liang, D. *Renewable and Sustainable Energy Reviews*, 2013, 18, 486–498.
China's emergence as a major force in clean energy development has profound implications for the world. A lack of understanding around the trajectory of China's surge in clean energy investment, and the seriousness of its impact on global clean energy development, demands a clear review of China's clean energy innovation. To this purpose, the paper analyses the technology innovation process and major players for technology innovation in a general sense. It then decodes the Chinese way of innovation, which reflects unique historical circumstances and development stage. The paper also explores the clean energy innovation with Chinese characteristics as well as analyses lessons from China in clean energy innovation. The paper concludes that China has become a global learning laboratory of clean energy technology. China's leadership in commercializing clean energy technology could ultimately help lower its costs and promote its commercialization globally. Nevertheless, China's clean energy innovation faces an ambiguous future due to the challenge in balancing and coordinating technology import and indigenous innovation.

14/01269 An assessment of Taiwan's energy policy using multi-dimensional energy security indicators

Chuang, M. C. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 301–311.
Facing the challenges of global warming, energy scarcity and energy price fluctuations, many countries consider energy security to be a major part of their energy policy and have started to develop relevant strategies. This study applies multi-dimensional energy security indicators to review the performance of Taiwan's energy security related measures and to analyse the impacts of the current energy policy on Taiwan's energy security. The results show that Taiwan's current energy policy is effective in improving the security of the energy supply. Taiwan's dependence on imported energy is rather high, however, which makes Taiwan vulnerable to international energy price fluctuations and liable to suffer from increased energy costs.

14/01270 Assessing energy security performance in the Asia Pacific, 1990–2010

Sovacool, B. K. *Renewable and Sustainable Energy Reviews*, 2013, 17, 228–247.
This article will create and apply an energy security index using 20 indicators that encompass economic, social, political and environmental aspects of energy security, and analyse the status of energy conditions in 18 countries from 1990 to 2010. Even though Malaysia and Myanmar (Burma) are both endowed with substantial energy resources, one has managed to improve its energy security greater than even fully industrialized countries such as the USA and European Union; the other has seen its energy security erode on virtually all fronts. At least three conclusions can be drawn from this exercise. First, according to the index, Malaysia was the country that most improved its energy security. Second, according to the index, Myanmar was the country that saw its energy security deteriorate most. It focused little on expanding energy access and instead directed efforts at energy exports to acquire foreign exchange. Third, and most troublingly, is that the index reveals tradeoffs within different components of energy security. Malaysia achieved its diversification and almost universal energy access only with large subsidies and one of the fastest growth rates in greenhouse gas emissions. Myanmar's extreme export oriented energy strategy leaves its population literally in the dark, and ironically its inability to effectively plan, its poor capacity and low levels of access, enable it to score favourably on environmental indicators (when land use change is excluded). The problem is that it appears that some elements of energy security, such as availability and affordability, can come only at the expense of others, such as sustainability and efficiency. This ability for components to conflict with each other may explain why most countries continue to struggle in their attempts to improve any holistic sense of energy security.

14/01271 Block configuration modeling: a novel simulation model to emulate building occupant peer networks and their impact on building energy consumption

Chen, J. *et al. Applied Energy*, 2013, 105, 358–368.
Recent research has shown that providing building occupants with eco-feedback regarding their own energy consumption and the consumption of others in their peer network can lead to substantial energy savings. While empirical eco-feedback studies have provided valuable insights into the dynamics of energy consumption behaviour and building occupant peer networks, such studies have faced challenges in examining consumption behaviour in larger and more complex peer networks. Computer simulation and random network models offer a solution to this scalability issue, but current random network models are limited in their ability to mimic real world building occupant networks. The authors propose a refined random network model, the block configuration model, and utilize it in an agent-based energy consumption simulation. Results indicate that the block configuration model is more accurate than conventional models when compared to empirical data from three different eco-feedback experiments. The block configuration model advances the understanding of the dynamics of occupant energy consumption and provides a tool to reduce energy consumption and associated emissions.

14/01272 Carbon reduction potentials of China's industrial parks: a case study of Suzhou Industry Park

Wang, H. *et al. Energy*, 2013, 55, 668–675.
Industrial parks are the economic engines for many China regions, but they also consume a great deal of energy and emit greenhouse gases. However, few empirical studies have examined these special communities. The authors selected the Suzhou Industrial Park (SIP) as a case study. Carbon emissions from SIP were accounted from the consumption perspective to analyse their characteristics. Results showed total carbon emissions grew 85.2% from 2005 to 2010, and carbon intensity (carbon emissions per unit of gross domestic product) decreased by 9%. Scenario analysis was then used to depict emissions trajectories under three different pathways. The total carbon emissions and per capita carbon emissions for SIP will undoubtedly increase in the near future under a business-as-usual scenario, improved-policy scenario, and low-carbon scenario; the carbon intensity will decrease by 38% under low-carbon scenario, but it will still be difficult to reach the national mitigation target. In addition, geographic-boundary-based

accounting methodology was applied for comparison analysis, carbon emissions show a large gap of 42.4–65.1% from 2005 to 2010, due to failure to account for cross-boundary emissions from imported electricity. Therefore, comprehensive analysis from a consumption perspective is necessary to provide a fair and comprehensive tool for China's local decision-makers to evaluate carbon mitigation potentials.

14/01273 Comparing the social costs of biofuels and fossil fuels: a case study of Vietnam

Le, L. T. *et al. Biomass and Bioenergy*, 2013, 54, 227–238.

Biofuel substitution for fossil fuels has been recommended in the literature and promoted in many countries; however, there are concerns about its economic viability. This study focuses on the cost-effectiveness of fuels, i.e. the social costs of biofuels and fossil fuels are compared for a functional unit defined as 1 km of vehicle transportation. The authors base their empirical results on a case study in Vietnam and compare two biofuels and their alternative fossil fuels: ethanol and gasoline, and biodiesel and diesel with a focus on the blends of E5 and E10 for ethanol, and B5 and B10 for biodiesel. At the discount rate of 4%, ethanol substitution for gasoline in form of E5 or E10 saves 33% of the social cost of gasoline if the fuel consumption of E5 and E10 is the same as gasoline. The ethanol substitution will be cost-effective if the fuel consumption of E5 and E10, in terms of $\mathrm{L\,km^{-1}}$, is not exceeding the consumption of gasoline by more than 1.7% and 3.5% for E5 and E10 respectively. The biodiesel substitution would be cost-effective if the fuel consumption of B5 and B10, in terms of $\mathrm{L\,km^{-1}}$ compared to diesel, would decrease by more than 1.4% and 2.8% for B5 and B10 respectively at the discount rate of 4%.

14/01274 CO_2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach

Saboori, B. and Sulaiman, J. *Energy*, 2013, 55, 813–822.

This study examines the cointegration and causal relationship between economic growth, carbon dioxide (CO_2) emissions and energy consumption in selected Association of Southeast Asian Nations (ASEAN) countries for the period 1971–2009. The recently developed autoregressive distributed lag methodology and Granger causality test based on vector error-correction model were used to conduct the analysis. There was cointegration relationship between variables in all the countries under the study with statistically significant positive relationship between carbon emissions and energy consumption in both the short and long-run. The long-run elasticities of energy consumption with respect to carbon emissions are higher than the short-run elasticities. This implies that carbon emissions level is found to increase in respect to energy consumption over time in the selected ASEAN countries. A significant non-linear relationship between carbon emissions and economic growth was supported in Singapore and Thailand for the long-run which supports the environmental Kuznets curve hypothesis. The Granger causality results suggested a bi-directional Granger causality between energy consumption and CO_2 emissions in all the five ASEAN countries. This implies that carbon emissions and energy consumption are highly interrelated to each other. All the variables are found to be stable suggesting that all the estimated models are stable over the study period.

14/01275 Current and future energy and exergy efficiencies in the Iran's transportation sector

Zarifi, F. *et al. Energy Conversion and Management*, 2013, 74, 24–34.

Transportation is the second largest energy consumer sector in Iran which accounts for 24% of total energy consumption in 2009. This large percentage (almost a quarter) of energy consumption necessitates the determination of energy and exergy flows and their respective losses, which will enable the reduction of both energy growth and its consequent environmental impacts in the near future. This paper attempts to analyse and investigate the energy and exergy utilization of the transportation sector in Iran for the period of 1998–2009. Additionally, the total energy consumption in each subsector and the overall energy and exergy efficiencies are predicted via scenario approach. A comparison of the overall energy and exergy efficiencies of Iran with six other countries is also presented. The results show that the overall energy and exergy efficiencies of transportation sector in Iran is higher than China and Norway, while it is lower than Saudi Arabia, Jordan, Turkey, and Malaysia for the year 2000. Road appears to be the most efficient subsector. The overall energy efficiency is determined to be in the range of 22.02% in 1998, to 21.49% in 2009, while the overall exergy efficiency is determine to be in the range of 21.47% in 1998, to 21.19% in 2009. The energy consumption in each subsector is predicted from 2010 to 2035. It was discovered that the overall energy and exergy efficiencies possesses an upward trend during this time period. Finally, some recommendations *vis-à-vis* the improvement of the energy and exergy efficiencies in Iranian transportation sector in the future was provided and duly discussed.

14/01276 Daily heat load variations in Swedish district heating systems

Gadd, H. and Werner, S. *Applied Energy*, 2013, 106, 47–55.

Heat load variations in district heating systems are both seasonal and daily. Seasonal variations have mainly its origin from variations in outdoor temperature over the year. The origin of daily variations is mainly induced by social patterns due to customer social behaviours. Heat load variations cause increased costs because of increased peak heat load capacity and expensive peak fuels. Seasonal heat load variations are well documented and analysed, but analyses of daily heat load variations are scarce. Published analyses are either case studies or models that try to predict daily heat load variations. There is a dearth of suitable assessment methods for more general analyses of existing daily load variations. In this paper, a novel assessment method for describing daily variations is presented. It is applied on district heating systems, but the method is generic and can be applied on every kind of activity where daily variations occur. The method was developed from two basic conditions: independent of system size and no use of external parameters other than of the time series analysed. The method consists of three parameters: the annual relative daily variation that is a benchmarking parameter between systems, the relative daily variation that describes the expected heat storage size to eliminate daily variations, and the relative hourly variation that describes the loading and unloading capacity to and from the heat storage. The assessment method could be used either for design purposes or for evaluation of existing storage. The method has been applied on 20 Swedish district heating systems ranging from small to large systems. The three parameters have been estimated for time series of hourly average heat loads for calendar years. The results show that the hourly heat load additions beyond the daily averages, vary between 3% and 6% of the annual volume of heat supplied to the network. Hereby, the daily variations are smaller than the seasonal variations, since the daily heat load additions, beyond the annual average heat load, are between 17% and 28% of the annual volume of heat supplied to the network. The size of short-term heat storage to eliminate the daily heat load variations has been estimated to a heat volume corresponding to about 17% of the average daily heat supplied into the network. This conclusion can also be expressed as an average demand of $2.5\,\mathrm{m^3}$ of heat storage volume per TJ of heat supplied by assuming a water temperature difference of 40 °C. The capacity for loading and unloading the storage should be equal to about half of the annual average heat load for heat supplied into the network.

14/01277 Decarbonizing Europe's power sector by 2050 – analyzing the economic implications of alternative decarbonization pathways

Jägemann, C. *et al. Energy Economics*, 2013, 40, 622–636.

The European Union aims to reduce greenhouse gas emissions by 80–95% in 2050 compared to 1990 levels. The transition towards a low-carbon economy implies the almost complete decarbonization of Europe's power sector, which could be achieved along various pathways. This paper evaluates the economic implications of alternative energy policies for Europe's power sector by applying a linear dynamic electricity system optimization model in over 36 scenarios. The authors find that the costs of decarbonizing Europe's power sector by 2050 vary between €139 and 633 billion (2010 value), which corresponds to an increase of between 11% and 44% compared to the total system costs when no CO_2 reduction targets are implemented. In line with economic theory, the decarbonization of Europe's power sector is achieved at minimal costs under a stand-alone CO_2 reduction target, which ensures competition between all low-carbon technologies. If, however, renewable energies are exempted from competition via supplementary renewable energy (RES-E) targets or if investments in new nuclear and carbon capture and storage (CCS) power plants are politically restricted, the costs of decarbonization significantly rise. Moreover, the authors find that the excess costs of supplementary RES-E targets depend on the acceptance of alternative low carbon technologies. For example, given a complete nuclear phase-out in Europe by 2050 and politically implemented restrictions on the application of CCS to conventional power plants, supplementary RES-E targets are redundant. While in such a scenario the overall costs of decarbonization are comparatively high, the excess costs of supplementary RES-E targets are close to zero.

14/01278 Deliberating on renewable and sustainable energy policies in China

Liu, L.-q. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 191–198.

This paper presents the current development situation of renewable and sustainable energy in China. The study considers application practice and distribution of different renewable energies, such as wind power, photovoltaics and tidal power. A detailed analysis of the renewable policies in China is also carried out, giving consideration as to how the Chinese government and economy can meet current and future energy needs, in terms of general principles, resource survey and development planning, industrial guidance and technical support, popularization and application, price management and cost allocation, and legal responsibility, and so on. With the increasing price of energy and power, it can be predicted that the development and the application of renewable energy in China will rapidly increase in the foreseeable future. As the Chinese central government and local governments have realized the importance of low carbon and sustainable development, the large-scale development of renewable resources can help to decrease carbon emissions and increase the supply of clean energy. Furthermore, as technology improves, the price of renewable energy equipment is likely to decrease, and so more and more clean power will come into ordinary people's homes. However, there are some obvious questions concerning renewable energy development in China, questions such as policy, economy, technology and market barriers. It is important to address these questions, and to do this will require the strong funding and policy support of central and local governments.

14/01279 Energy consumption, energy R&D and real GDP in OECD countries with and without oil reserves

Wong, S. L. *et al. Energy Economics*, 2013, 40, 51–60.

The objective of the study is to shed light on the contributions of energy consumption and energy R&D on economic growth. The authors examine two sets of causal relationship between: (1) capital stock, energy consumption and real gross domestic product (GDP) and (2) capital stock, energy R&D and real GDP using panel-based fully-modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) for 20 OECD countries over the period of 1980–2010. Since different countries may respond differently to energy consumption and energy R&D, the sample is further divided into two groups: OECD countries with oil reserves and without oil reserves. Similarly, energy consumption and energy R&D are also further divided into fossil fuel energy and renewable energy. The results show that the role of energy R&D should not be overlooked and fossil fuel R&D is found to drive economic growth more than fossil fuel consumption. The findings also show that while capital stock and fossil fuels are the key factors driving economic growth, renewable energy promotes real output, specifically in the countries without oil reserves.

14/01280 Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran

Tabatabaie, S. M. H. *et al. Renewable Energy*, 2013, 51, 7–12.

The purposes of this study were to determine energy use pattern and investigate the relationships between energy inputs and yield, cost inputs and income for pear production in the Tehran province of Iran. In this study, data were collected by administering a questionnaire in face-to-face interviews in the production year of 2009/2010. This paper presents a comprehensive picture of the current status of energy consumption and some energy indices like energy ratio, energy productivity, specific energy, net energy and energy intensiveness. Results showed that the total energy input of $172{,}608.43\,\mathrm{MJ\,ha^{-1}}$ was required for pear production. Among input energy sources, electricity energy with share of 78% of total input energy had the highest share. The energy use efficiency and energy productivity were found as 0.51 and $0.27\,\mathrm{kg\,MJ^{-1}}$, respectively. To investigate the relationships between energy inputs and yield, cost inputs and income, Cobb–Douglas production function was selected as the best function. Sensitivity analysis of energy and cost inputs was carried out using the marginal physical productivity technique. Economic analysis of pear production was carried out and total cost of pear production was obtained as $\$11{,}936.97\,\mathrm{h^{-1}}$. Also the benefit to cost ratio was calculated as 3.11.

14/01281 Environmental Kuznets curve in Romania and the role of energy consumption

Shahbaz, M. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 165–173.

This study probed the dynamic relationship between economic growth, energy consumption and CO_2 emissions for period 1980–2010 in Romania. The results confirmed the relationship between economic growth, energy consumption and energy pollutants. The empirical evidence reveals that environmental Kuznets curve (EKC) was found both in long and short runs in Romania. Further, energy consumption is major contributor to energy pollutants. The democratic regime has shown a significant contribution to the decline in CO_2 emissions through effective implementation of economic policies and financial development and has improved the environment, i.e. by reducing CO_2 emissions, by redirecting the resources to environment friendly projects.

14/01282 Evaluating the relationships among economic growth, energy consumption, air emissions and air environmental protection investment in China

Zhang, X. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 259–270.

This paper analysed the interactions between China's economic growth and its energy consumption, air emissions and air environmental protection investment during 2000–2007. Conventional energy and emergy are applied to quantify energy consumption and emissions' impact, respectively. The five indicators based on money, energy and emergy, including ratio of non-renewable energy to renewable energy, energy use per unit gross domestic product (GDP), environmental cost per unit GDP, impact of emissions per unit energy consumption, and environmental benefit per unit environmental protection investment, are presented to depict the relationships among economic growth and energy consumption and impact of air emissions and air environmental protection investment. The results show that energy consumption rapidly rises with China's fast economic growth; however, energy efficiency and environmental loading intensity from energy consumption are reduced simultaneously but their improvements fall far behind economic growth rate. The impact of air emissions, mainly composed of impact of emissions on human health (especially dust), is slightly decreased. The performance of air environmental protection investment declined in the study period. Generally speaking, the conflict among economy, energy and air environment protection is slightly mitigated but still acute due to great dependence of China's economy on fossil energy and inefficient environmental protection measures. This paper also discusses the corresponding issues and puts forward some related suggestions.

14/01283 Experts' view on Finland's energy policy

Valkila, N. and Saari, A. *Renewable and Sustainable Energy Reviews*, 2013, 17, 283–290.

By international standards Finland's per capita emissions of carbon dioxide are fairly high. This study gives an outline of Finland's current energy policy, the threats and opportunities in the energy sector, and future scenarios in terms of energy production, use of nuclear power and the Finnish way of life. The aim of this study was to examine Finnish energy policy by means of a qualitative interview survey of selected energy sector experts. The results of the study indicate a lack of coherence in Finland's present energy policy. Economic uncertainties show up as the most significant threats affecting the energy sector. The most significant opportunities for Finland focus on the prospects for international exports of products, services and expertise based on Finnish energy efficiency and energy savings. Unanimity was expressed on the future direction of energy production in Finland, namely that it should focus on the development of renewable energy sources and the diversification of production technologies, although there were conflicting views among the experts interviewed regarding the use of nuclear power. In regard to the Finnish way of life, the most significant changes anticipated are under the themes of travel, housing, leisure and energy attitudes.

14/01284 Heterogeneous effects of regulation on the efficiency of the electricity industry across European Union countries

Pompei, F. *Energy Economics*, 2013, 40, 569–585.

This paper focuses on the relationship between the stringency of regulation (OECD indicators) and total factor productivity (TFP) growth in the electricity sectors of 19 European Union countries for the period 1994–2007. Both the OECD regulatory indicator and the TFP growth index have been decomposed in order to bring to light a complex picture of interrelations in which the negative impact of the overall regulation on productivity is the result of opposite forces. Estimation results indicate that only the stringency of entry regulation significantly reduces technological change, whereas vertical integration exhibits a negative and significant impact only on the catching up process (pure efficiency change). Lastly, the authors found an interesting result concerning the explanatory variables of the scale efficiency change: in this case only public ownership matters, in other terms high levels of public in the structure ownership of electric companies guarantee improvements in reaching the optimal scale of production. These heterogeneous effects are also confirmed when the authors used a different measure of efficiency, that is, the distance of the actual from the optimal reserve margin.

14/01285 Impact of various biodiesel fuels obtained from edible and non-edible oils on engine exhaust gas and noise emissions

Fattah, I. M. R. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 552–567.

Increasing demand for fossil fuels due to an improving quality of life, significant growth of population, transportation and the basic industry sectors has caused serious environmental problems. Moreover, a rapid decline in fossil fuels has led scientists and researchers to look for new alternatives. In this regard, alternative fuels such as biofuels are becoming increasingly important due to environmental and energy concerns. Biofuels are commonly referred to as first generation, which are produced primarily from food crops. However, the use of edible oil to produce biodiesel in many countries is not feasible in view of a big gap in the demand and supply of such oils for dietary consumption. This paper critically reviews the facts and prospects of biofuel utilization, especially focusing on three edible biodiesels, namely soybean, rapeseed, palm and two non-edible, namely jatropha and cottonseed to reduce engine exhaust gas, noise emission and petro dependency. Based on various biofuel feedstocks, this paper generally found that biodiesel fuels are considered as offering many benefits, including sustainability, reduction of greenhouse gas emissions and many harmful pollutants along with noise emission, regional development, social structure and agriculture, and security of supply.

14/01286 Mainstreaming ecosystem services in European policy impact assessment

Helming, K. *et al. Environmental Impact Assessment Review*, 2013, 40, 82–87.

The concept of ecosystem services as developed for the Millennium Ecosystem Assessment (MA) is currently the most extensive, international, scientific concept dealing with the interaction between the world's ecosystems and human well-being. The fundamental asset is seen in the relevancy of the concept at the science–policy interface. Albeit, the mainstreaming of ecosystem services into policy making requires a framework that allows the transition of the scientific concept into the rationale of policy making. The authors hypothesize that the procedure of policy impact assessment is a suitable venue for this transition. This brings up two questions: (1) where in the process of policy impact assessment can ecosystem services be mainstreamed? (2) How can the impact on ecosystem services properly be accounted for? This study distinguishes two groups of policy cases: explicit cases directly addressing ecosystem services, and implicit cases of policies that follow other purposes but may have unintended impacts on ecosystem services as a side effect. The second group covers a wide range of policies for which the authors set out a framework for mainstreaming of ecosystem services. The framework is exemplary designed for the instrument of *ex ante* impact assessment at European policy-making level. The authors reveal that the two concepts of the MA and of the European policy impact assessment are indeed compatible, which makes the integration of the ecosystem service concept possible. It was concluded that the linkage of the scientifically validated concept of ecosystem services with the policy concept of impact assessment has the potential of improving the credibility of the latter.

14/01287 Possible impact of 2020 bioenergy targets on European Union land use. A scenario-based assessment from national renewable energy action plans proposals

Scarlat, N. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 595–606.

According to renewable energy directive 2009/28/EC, European Union (EU) member states should, by 2020, increase the use of renewable energy to 20% of gross final energy consumption and to reach a mandatory share of 10% renewable energy in the transport sector. This study aims to quantify the impact of 2020 bioenergy targets on the land use in the EU, based on the projections of the national renewable action plans (NREAPs) in four scenarios. Scenario 1: bioenergy targets according to NREAPs. Scenario 2: bioenergy targets according to NREAPs, no second generation biofuels. Scenario 3: bioenergy targets according to NREAPs, reduced import of biofuels and bioliquids. Scenario 4: bioenergy targets according to NREAPs, high imports of biofuels and bioliquids. This study also considers the credit for co-products generated from biofuel production. The analysis reveals that the land used in the EU for bioenergy would range between 13.5 and 25.2 Mha in 2020. This represent between 12.2% and 22.5% of the total arable land used and 7.3% and 13.5% of the utilized agricultural area (UAA). In the NREAPS scenario, about 17.4 Mha would be used for bioenergy production, representing 15.7% of arable land and 9.4% of UAA. The increased demand from biofuels would lead to an increased generation of co-products, replacing conventional fodder for animal feed. Considering the co-products, the land used for bioenergy would range between 8.8 and 15.0 Mha in 2020 in the various scenarios. This represents between 7.9% and 13.3% of the total arable land used in the EU and 4.7% and 8.0% of the UAA. In the NREAPS scenario, when co-products are considered, about 10.3 Mha would be used for biofuels, bioliquids and bioenergy production, representing 9.3% of arable land and 5.6% of agricultural land. This study further provides detailed data on the impact on land use in each member state.

14/01288 Predictive control methods to improve energy efficiency and reduce demand in buildings

Salsbury, T. *et al. Computers & Chemical Engineering*, 2013, 51, 77–85.

This paper describes the application of predictive control strategies to energy systems in buildings. Two new control methods were presented. The first focused on vapour–compression cycle systems that are used in many residential and small-sized buildings and are responsible for a large portion of total energy costs. Small improvements in the efficiency of operation of these systems can therefore translate into significant cost savings. An model predictive control (MPC) strategy was used that directly handled inherent interactions in the system enabling improved setpoint tracking and disturbance rejection. The strategy also included economic optimization whereby the compressor speed was used as a proxy for energy use. Important system constraints were also integrated in the control strategy rather than being implemented separately as is the case in most current systems. The control objective was to satisfy setpoint tracking requirements within the constraint bounded region of operation and at the same time minimize the energy used by the compressor. Results showed significant improvements over the current state of the art. The second control strategy was designed to address the seemingly intractable problem of how to reduce energy costs when electricity charges include peak demand charges during the on-peak period. Demand reduction has been formulated as an economic model predictive control problem, which is appropriate for the nature of the unsteady disturbances and dynamic price changes that happen in the same time scale as the building thermal dynamics. In the proposed MPC algorithm, the min–max optimization problem is transformed into a linear program, which is solved at each time step. The proposed method aims at minimizing the costs on the daily basis. It was shown by simulation that under the time-of-use electrical pricing structure, MPC brings substantial cost savings for a simulated building. Challenges remain in testing the control strategy in real buildings, large-scale buildings, and a group of buildings as a complex. In summary, both of the control methods presented here show promise as a way to reduce energy costs in buildings through smarter and more integrated control. However, there are still a number of issues that need to be resolved before the technology is adopted more broadly. One problem is that both methods require a model of the system that is being optimized. Obtaining a model can be a major cost factor. Both approaches fit linear models to systems that are non-linear and also time-varying. Further research needs to address the issue of model accuracy and ascertain by how much the use of inevitably inaccurate models will affect the performance of the control strategies. Robustness also needs to be analysed because of the fact that linking several previously independent control loops makes it possible that control failure would affect much larger portions of building operation than would previously have been the case. Safeguards against these system-wide failures therefore need to be developed before deployment. Finally, the issues of tuning and set-up need to be carefully researched in the context of the low cost buildings environment, and assumption of minimal expertise available on-site.

14/01289 Renewable energy subsidies: second-best policy or fatal aberration for mitigation?

Kalkuhl, M. *et al. Resource and Energy Economics*, 2013, 35, (3), 217–234.

This paper evaluates the consequences of renewable energy policies on welfare and energy prices in a world where carbon pricing is imperfect and the regulator seeks to limit emissions to a (cumulative) target. The imperfectness of the carbon price is motivated by political concerns regarding distributional effects of increased energy prices. Hence, carbon prices are considered to be temporarily or permanently absent or endogenously constrained by their effect on energy prices. The authors use a global general equilibrium model with an intertemporal fossil resource sector and calculate intertemporally optimal policies from a broad set of policy instruments including carbon taxes, renewable energy subsidies and feed-in-tariffs, among others. If carbon pricing is permanently missing, mitigation costs increase by a multiple (compared to the optimal carbon pricing policy) for a wide range of parameters describing extraction costs, renewable energy costs, substitution possibilities and normative attitudes. Furthermore, the authors show that small deviations from the second-best subsidy can lead to strong increases in emissions and consumption losses. This confirms the rising concerns about the occurrence of unintended side effects of climate policy – a new version of the green paradox. Smart combinations of carbon prices and renewable energy subsidies, however, can achieve ambitious mitigation targets at moderate additional costs without leading to high energy price increases.

14/01290 The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis

Shahbaz, M. *et al. Energy Economics*, 2013, 40, 8–21.

This study investigates the relationship between energy use and economic growth by incorporating financial development, international trade and capital as important factors of production function in case of China over the period of 1971–2011. The autoregressive distributed lag bounds testing approach to cointegration was applied to examine long run relationship among the series while stationarity properties of the variables was tested by applying structural break test. The empirical evidence confirmed long run relationship among the variables. The results showed that energy use, financial development, capital, exports, imports and international trade have positive impact on economic growth. The Granger causality analysis revealed that unidirectional causal relationship running from energy use to economic growth. Financial development and energy use Granger cause each other. There is bidirectional causality between international trade and energy use. The feedback relation exists between financial development and international trade. There is also bidirectional causality exists between capital and energy demand, financial development and economic growth and, international trade and economic growth. This paper makes significant contribution in energy economics and opens up new direction for policy makers to explore new and alternative sources of energy which would be helpful in meeting the rising demand of energy due to sustained rate of economic growth.

14/01291 The impact of residential density on vehicle usage and fuel consumption: evidence from national samples

Kim, J. and Brownstone, D. *Energy Economics*, 2013, 40, 196–206.

This paper investigates the impact of residential density on household vehicle usage and fuel consumption. The authors estimate a simultaneous equations system to account for the potential residential self-selection problem. While most previous studies focus on a specific region, this paper uses national samples from the 2001 National Household Travel Survey. The estimation results indicate that residential density has a statistically significant but economically modest influence on vehicle usage, which is similar to that in previous studies. However, the joint effect of the contextual density measure (density in the context of its surrounding area) and residential density on vehicle usage is quantitatively larger than the sole effect of residential density. Moving a household from a suburban to an urban area reduces household annual mileage by 18%. The authors also find that a lower neighbourhood residential density induces consumer choices toward less fuel-efficient vehicles, which confirms the finding in an earlier study.

14/01292 Toward renewable energy geo-information infrastructures: applications of GIScience and remote sensing that build institutional capacity

Calvert, K. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 416–429.

Sustained policy support is necessary in order to drive a transition toward renewable energy (RE). The ability to realize RE policy objectives is constrained by a range of geographic factors related to resource potential, the distribution of resources, land availability/suitability, the absorptive capacity of proximal infrastructure, and local socio-political acceptance. With this in mind, this paper provides a systematic review of how geographic information science and remote sensing techniques have been applied to reduce uncertainties surrounding renewable energy development, with emphasis on policy and planning needs. The concept of a ‘geo-information infrastructure’ is used to bring coherence and direction to this growing body of literature. The review highlights four underdeveloped research areas, including: Resolving issues of scalar discordance through comprehensive analysis at local and regional scales; mapping interactions in space of multiple supply options to deliver more accurate and sophisticated estimates of RE potential in an area and to identify competitive and symbiotic land-use situations; using energy resource maps as primary inputs into the development of technology road-maps; and developing geographically explicit indicators which can signal priority areas for RE recovery based on social and environmental returns on investments. In each case, suggestions moving forward are provided. The paper identifies knowledge-based institutional networking as a pathway through which local and regional public authorities can be equipped with the resources necessary to build and mobilize a geo-information infrastructure.

14/01293 What moves wind energy development in China? Show me the money!

Lam, J. C. K. *et al. Applied Energy*, 2013, 105, 423–429.

China’s wind industry has grown rapidly over the past decade. Continued growth in this industry is critical for China’s domestic energy security and the global environment. However, little is known about the microeconomic drivers that move wind energy development in China. Based on a survey of experts in mainland China and the Hong Kong Special Administrative Region, this paper finds that the most important drivers of wind energy investment in China are perceived to be those that can have an immediate impact on a wind energy developer’s cash flow: government financial assistance, easy and inexpensive transmission access, wind energy cost decline, and a high feed-in-tariff. A renewable portfolio standard, tax incentives and international research and development cooperation are seen as less important. These findings underscore the importance of reducing the financial risk in wind energy development. However, none of the key drivers is directly tied to energy output, which suggests that China’s wind energy policies must be modified to incentivize energy output, rather than just installed capacity.

Energy conservation

14/01294 Action dependent heuristic dynamic programming for home energy resource scheduling

Fuselli, D. *et al. International Journal of Electric Power & Energy Systems*, 2013, 48, 148–160.

Energy management in smart home environment is nowadays a crucial aspect on which technologies have been focusing on in order to save costs and minimize energy waste. This goal can be reached by means of an energy resource scheduling strategy provided by a suitable optimization technique. The proposed solution involves a class of adaptive critical designs called action-dependent heuristic dynamic programming (ADHDP) that uses two neural networks, namely the action and the critic network. This scheme is able to minimize a given utility function over a certain time horizon. In order to increase the performances of the ADHDP algorithm, suitable particle swarm optimization (PSO) based procedures are used to pretrain the weights of the action and the critic networks. The results provided by PSO techniques and by a non-optimal baseline approach are also used as elements of comparison. Computer simulations have been carried out in different residential scenarios. An historical data set for solar irradiation has been used to simulate the behaviour of a photovoltaic array to obtain renewable energy and the main grid is used to supply the load and charge the battery when necessary. The results confirm that the ADHDP is able to reduce the overall energy cost with respect to the baseline solution and the PSO techniques. Moreover, the validity of this method has also been shown in a more realistic context where only forecasted values of solar irradiation and electricity price can be used.

14/01295 An approach to energy savings and improved environmental impact through restructuring Jordan’s transport sector

Al-Ghandoor, A. *Renewable and Sustainable Energy Reviews*, 2013, 18, 31–42.

This paper illustrates a new approach to forecast the potential energy savings and environmental impact of adopting energy efficient practices in the Jordanian transportation sector. This approach is based on an adaptive neuro-fuzzy inference system (ANFIS) and the double exponential smoothing techniques. The ANFIS model has been developed using socio-economic and transport related indicators based on annual number of vehicles, vehicle owner level, income level and fuel prices in Jordan. The double exponential smoothing technique has been used to forecast the different transport indicators to feed the developed ANFIS model in order to forecast the transport energy demand for the next two decades. The model has been validated using testing data and has showed very accurate results of 97%. The results show that the transport energy demand is expected to increase at 4.9% per year for 2011–2030. As an example of the energy efficiency improvement in the transportation sector, this paper examines potential benefits that can be achieved through the introduction of diesel cars to the passenger cars market in Jordan. Five scenarios are suggested for implementation and investigated using the new approach on the basis of local and global trends over the period 2011–2030. It is demonstrated that introducing diesel passenger cars can slow down the growth of energy consumption in the transportation sector resulting in significant savings in the national fuel bill. It is also shown that this is an effective and feasible option for cutting down CO_2 emissions.

14/01296 Analysis of building energy consumption parameters and energy savings measurement and verification by applying eQUEST software

Ke, M.-T. *et al. Energy and Buildings*, 2013, 61, 100–107.

This study examines the energy-saving performance contract (ESPC) of an office building by applying IPMVP Option D in combination with the energy analysis model established for the building by eQUEST simulation software to calibrate energy consumption simulation results using actual electricity billing data. The rates of error between actual values and energy consumption simulation results from the calibrated and uncalibrated models are then explored to confirm the accuracy of the calibrated model. Finally, the calibrated model is used to examine the impact of energy consumption parameter changes on the overall energy consumption in a building. The results indicate that, compared to actual energy consumption, the mean bias error (MBE) and root mean square error (RMSE) for uncalibrated simulation results are 24.48% and 125,050, whereas the MBE and RMSE for calibrated simulation is 0.37% and 34,197. When lighting power density increases or decreases by 50%, overall energy consumption decreases by 30.78% or increases by 31.19%, respectively. Therefore, illumination density has the greatest impact on energy consumption. This study also recommends that accurate parameter settings be confirmed when using

IPMVP Option D simulation verification to ensure a highly accurate building energy consumption model, thereby facilitating the measurement and verification of energy savings.

14/01297 Asymmetric substitutability between energy and capital: evidence from the manufacturing sectors in 10 OECD countries

Kim, J. and Heo, E. *Energy Economics*, 2013, 40, 81–89.

This paper investigates the substitutability between energy and capital in the manufacturing sectors of 10 OECD countries since 1980 by applying a cost function approach that has been widely used to analyse industrial energy demand. First, the authors attempt to determine the source of the disagreement in the literature on the substitutability between energy and capital and reach a conclusion regarding the substitutability between energy and capital. Dividing energy and capital into sub-inputs, the authors analyse their substitutability. The empirical results indicate that fuel tends to complement capital in most countries, whereas electricity and capital are substitutes. Thus, this study confirms that heterogeneity in energy sources is a primary component of the systematic variation in the substitutability between energy and capital. Second, the authors examine asymmetric substitutability between energy and capital by estimating the Morishima elasticity of substitution. The estimates of the Morishima elasticity of substitution demonstrate that the substitution of energy for capital has dominated the substitution of capital for energy. This asymmetric substitutability is natural from the producer perspective because capital costs are much greater than energy costs in most countries. These results imply that the adoption of energy-saving technologies has not been induced in response to increased energy prices.

14/01298 Cable length optimization for trawl fuel consumption reduction

Khaled, R. *et al. Ocean Engineering*, 2013, 58, 167–179.

A numerical method for optimization of the cable lengths in trawls with respect to the ratio between the estimated trawl drag and the predicted catch efficiency is developed and applied. The trawl cables of interest are warps, bridles, headline and footrope. The optimization algorithm applies an ordered sequential process changing one cable length at the time. It is assumed in the predictions that the catch efficiency of the trawl is proportional with the trawl mouth area. In a case study optimizing a bottom trawl used on a research vessel by applying the new method it is predicted that it would be possible to reduce the ratio between trawl drag and catch efficiency by up to 46% by optimizing the cable lengths. Thus this would enable a considerable reduction in fuel consumption to catch a specific amount of fish. Moreover, an increase is predicted in the value of the trawl mouth area leading to better catching efficiency without increase in otter door drag.

14/01299 Effects of energy conservation and emission reduction on energy efficiency retrofit for existing residence: a case from China

Liu, Y. and Guo, W. *Energy and Buildings*, 2013, 61, 61–72.

The aim of this paper is to analyse the effects of energy conservation and emission reduction (ECER) on energy efficiency retrofit (EER) for existing residence in northern heating regions of China. Based on building energy consumption (BEC) testing data during heating period before and after the retrofit, combined with the theoretical calculation of BEC, the ECER effects are analysed through an actual case of existing residential retrofit; meanwhile, residential electricity consumption between the retrofit building and non-retrofitted buildings is also compared. The case study results show that: (1) actual ECER effects of EER are obviously different from those analysed by the theoretical calculation; (2) existing residential EER will have significant impacts on ECER; (3) building external wall retrofit always makes the largest contribution to ECER in high energy-consuming building, followed by external window retrofit; (4) the retrofit of building envelopes should be carried out with indoor heating system retrofit, heat metering and charging system together; otherwise, the phenomenon of 'energy efficient buildings do not save energy' will appear; (5) the EER of existing building in northern heating regions will not only cause the obvious reduction of BEC in winter, but also lead to electricity consumption saved in summer.

14/01300 Energy saving in lighting system with fuzzy logic controller which uses light-pipe and dimmable ballast

Görgülü, S. and Ekren, N. *Energy and Buildings*, 2013, 61, 172–176.

Approximately 20% of the electricity consumed in the world is for lighting. A more efficient use of the sun for lighting would save electricity. The aim of this study is to illuminate a windowless room via a light-pipe and dimmable electronic ballasts. A light-pipe is used for the illumination of the space during the daytime. In case of inadequate daylight, artificial lighting is made via dimmable electronic ballasts and fluorescence lamps. Artificial lighting is supervised by a fuzzy logic control system to keep the illumination level at 350 lux. When there is motion in the room the system works with a motion sensor, which enables energy saving. Additionally, dimming the lamps result in conversation of the electrical energy used for illumination. After the experimental studies, 350 lux value targeted in the workplace is achieved with ±10 lux error.

14/01301 Energy usage and technical potential for energy saving measures in the Swedish residential building stock

Mata, E. *et al. Energy Policy*, 2013, 55, 404–414.

This paper provides an analysis of the current energy usage (net energy and final energy by fuels) and associated carbon dioxide (CO_2) emissions of the Swedish residential building stock, which includes single-family dwellings and multi-family dwellings. Twelve energy saving measures (ESMs) are assessed using a bottom-up modelling methodology, in which the Swedish residential stock is represented by a sample of 1400 buildings (based on data from the year 2005). Application of the ESMs studied gives a maximum technical reduction potential in energy demand of 53%, corresponding to a 63% reduction in CO_2 emissions. Although application of the investigated ESMs would reduce CO_2 emissions, the measures that reduce electricity consumption for lighting and appliances will increase CO_2 emissions, since the saved electricity production is less CO_2-intensive than the fuel mix used for the increased space heating required to make up for the loss in indirect heating obtained from lighting and appliances.

14/01302 Hybrid distillation/melt crystallization process using thermally coupled arrangements: optimization with evolutive algorithms

Bravo-Bravo, C. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 25–38.

Innovative hybrid processes offer significant cost savings, particularly for azeotropic or close-boiling mixtures. Hybrid separation processes are characterized by the combination of two or more different unit operations, which contribute to the separation task by different physical separation principles. Despite of the inherent advantages of hybrid separation processes, they are not systematically exploited in industrial applications due to the complexity of the design and optimization of these highly integrated processes. This study considers a hybrid distillation/melt crystallization process, using conventional and thermally coupled distillation sequences. The design and optimization were carried out using, as a design tool, a multi-objective genetic algorithm with restrictions coupled with the process simulator Aspen Plus^{TM}, for the evaluation of the objective function. The results show that this hybrid configuration with thermally coupled arrangements is a feasible option in terms of energy savings, capital investment and control properties.

14/01303 Large-scale control of domestic refrigerators for demand peak reduction in distribution systems

Niro, G. *et al. Electric Power Systems Research*, 2013, 100, 34–42.

This paper presents a practical strategy for large-scale control of domestic refrigerators for demand peak reduction in distribution systems. Due to thermodynamics particularities, the refrigerators can be flexibly disconnected from the network for short periods without impacting negatively on their delivered services. Besides, combined with the fact that these loads are present in almost every residential home, the potential for energy consumption reduction is considerable. In this context, the objective of this work is threefold: develop an adequate model for simulation of individual and group of refrigerators; implement practical strategies to manage the demand of refrigerators during peak time; and analyse the impact of such strategies in the operation of distribution systems. The simulation results confirmed that the proposed strategy can contribute not only for reducing peak demand, but also for improving losses and voltage profile of power distribution systems.

14/01304 Lessons for integrated household energy conservation policy from Singapore's southwest Eco-living program

He, H. Z. and Kua, H. W. *Energy Policy*, 2013, 55, 105–116.

This study describes a district-level energy intervention and conservation programme designed and implemented with the help of community stakeholders, which include students and staff of an educational institution, the National University of Singapore, a local non-governmental environmental group in Singapore and the district government. The programme – known formally as the Eco-living Program – was funded by the district government and implemented in the Hong Kah North Residential Council in the south western part of Singapore. The research objectives are three-fold: (1) compare the effectiveness of different intervention methods, based on self-reported behaviour scores and actual electricity reduction; (2) investigate how behaviour and electricity consumption are influenced by values, situational and psychological factors; (3) assess the effectiveness of different methods of intervention and provide recommendations for improvement. It was found that a combined use of leaflets and stickers resulted in highest (that is, 15.8%) reduction in average consumption. Ease of practising the recommended energy conservation actions is a strong motivator to change energy consumption behaviour. This programme exemplifies the important role that community-initiated bottom-up programmes can play in promoting sustainable consumption with the financial support from the local (district) government.

14/01305 Modeling for insight using Tools for Energy Model Optimization and Analysis (Temoa)

Hunter, K. *et al. Energy Economics*, 2013, 40, 339–349.

This paper introduces Tools for Energy Model Optimization and Analysis (Temoa), an open-source framework for conducting energy system analysis. The core component of Temoa is an energy economy optimization (EEO) model, which minimizes the system-wide cost of energy supply by optimizing the deployment and utilization of energy technologies over a user-specified time horizon. The design of Temoa is intended to fill a unique niche within the energy modelling landscape by addressing two critical shortcomings associated with existing models: an inability to perform third party verification of published model results and the difficulty of conducting uncertainty analysis with large, complex models. Temoa leverages a modern revision control system to publicly archive model source code and data, which ensures repeatability of all published modelling work. From its initial conceptualization, Temoa was also designed for operation within a high performance computing environment to enable rigorous uncertainty analysis. The authors present the algebraic formulation of Temoa and conduct a verification exercise by implementing a simple test system in both Temoa and MARKAL, a widely used commercial model of the same type. In addition, a stochastic optimization of the test system is presented as a proof-of-concept application of uncertainty analysis using the Temoa framework.

14/01306 On-farm energetics of mango production in Nigeria

Jekayinfa, S. O. *et al. Renewable Energy*, 2013, 51, 60–63.

The aims of this study were to determine direct input energy, indirect energy and other energy use indices in mango production in a group of mango plantation of a research farm in Nigeria. The study also estimated the economic indices of mango production in the study area and energy potentials of mango by-products. The average energy consumption of the plantations investigated in this study is 15,015.16 MJ ha^{-1}. Out of the total energy, 93% was direct and 7% was indirect. Renewable energy accounted for 21% and energy usage efficiency was found to be 1.3. The total energy input into the production of 1 kg of mango was estimated to be 0.70 MJ. The dominant contribution to input was energy in the form of diesel used in tractor operation and captive power generation (56%), followed by human labour used for land preparation, cultural practices and harvesting (33%), machinery (5%) and chemicals, mainly herbicides (4%). The use of energetically available residues of mango could give an average value addition of 57,067 MJ/ha. The cost of mango production per hectare was found to be 2246 \$ ha^{-1}. As a result of benefit-cost ratio value (1.24), energy use efficiency and the energy value addition from mango residues, mango production was found to be economically efficient in the study area.

14/01307 Optimal green energy management for island resorts in Malaysia

Ashourian, M. H. *et al. Renewable Energy*, 2013, 51, 36–45.

This paper proposes optimum green energy systems for electricity generation of island resorts in Malaysia. A combination of solar energy and wind energy as intermittent renewable energy sources with a fuel cell system and a battery storage energy system as a backup to the green energy system is introduced for this study. This system is eco-friendly, economical over the long-term, highly sustainable and reliable. In addition, a diesel-based energy system as a non-green system is compared with the proposed green system. The National Renewable Energy Laboratory's HOMER software is used to determine and compare the optimal configuration green energy system with the diesel-based energy system in terms of net present cost, sensitivity analysis and pollutant gas emission. The feasibility and assessment of the proposed system is evaluated by utilizing the load profile and considering the geographical condition of a village (Juara village in Tioman Island) with approximately 30 chalets located in southern Malaysia. HOMER uses two types of load profiles for each given year. The first load profile is used during the presence of tourists, and the second profile is used when the locals are the main inhabitants of the island. The optimization management for the green energy system is performed through unit sizing to find the optimum power management analysis and to perform cost analysis of the system. The potential of renewable energy as well as a diesel-based energy system to meet the power demand for such a stand-alone system is considered. Technically feasible and economically viable green energy systems as prospective plans are explored in this study.

14/01308 Performance evaluation of ventilation radiators

Myhren, J. A. and Holmberg, S. *Applied Thermal Engineering*, 2013, 51, (1–2), 315–324.

A ventilation radiator is a combined ventilation and heat emission unit currently of interest due to its potential for increasing energy efficiency in exhaust-ventilated buildings with warm water heating. This paper presents results of performance tests of several ventilation radiator models conducted under controlled laboratory conditions. The purpose of the study was to validate results achieved by computational fluid dynamics (CFD) in an earlier study and identify possible improvements in the performance of such systems. The main focus was on heat transfer from internal convection fins, but comfort and health aspects related to ventilation rates and air temperatures were also considered. The general results from the CFD simulations were confirmed; the heat output of ventilation radiators may be improved by at least 20% without sacrificing ventilation efficiency or thermal comfort. Improved thermal efficiency of ventilation radiators allows a lower supply water temperature and energy savings both for heating up and distribution of warm water in heat pumps or district heating systems. A secondary benefit is that a high ventilation rate can be maintained all year around without risk for cold draught.

14/01309 Simultaneous study on energy consumption and emission generation for an ethylene plant under different start-up strategies

Fu, J. and Xu, Q. *Computers & Chemical Engineering*, 2013, 56, 68–79.

Chemical plant start-ups are very critical dynamic operations, which normally consume huge amount of energy and also generate large quantities of off-spec products for flaring, causing significant and intensive air emissions. Many studies have been individually conducted on energy savings or emission reductions under plant normal conditions. However, quantitative studies on simultaneous energy consumption and emission generation for chemical plant start-ups are still lacking. In this study, plant-wide dynamic simulations are employed to investigate energy consumption and emission generation for an ethylene plant under different start-up strategies. Dynamic modelling and simulations for two start-up designs associated with three start-up operating procedures are performed. Based on plant-wide dynamic simulations, dynamic profiles of energy consumption and emission generation during the plant start-up are obtained and analysed. Details of energy accounting on cooling and heating duties of key distillation towers, auxiliary heat exchanger duties, and power consumption for compressor system are provided for each start-up case. Through comprehensive analysis, the most desirable start-up solution is identified. This virtual study not only characterizes the emission generation during the plant start-up, supporting flare minimization activities that benefits environmental sustainability, but also enhances critical research on energy and raw material savings during the plant start-up that will benefit the industrial sustainability.

14/01310 Supplier choice and WTP for electricity attributes in an emerging market: the role of perceived past experience, environmental concern and energy saving behavior

Amador, F. J. *et al. Energy Economics*, 2013, 40, 953–966.

This study analyses customers' preferences and their willingness to pay (WTP) for certain service attributes in an electricity supplier choice context. Specifically, a stated preference choice experiment is conducted in the Canary Islands' residential market where limited competition exists. Preferences for different electricity suppliers and three level-of-service attributes are investigated, namely, supply reliability, share of renewable energies and availability of a complementary energy audit service. The results might be interpreted as an indication of different aspects new firms need to consider if they plan to enter in the market. There is an opportunity for new companies to establish in the market, though evidence of brand loyalty to the current company and/or significant switching costs are also found, especially in the case of older people. Regarding the estimated WTP, several results should be highlighted. First, customers who have experienced more serious outages in the past tend to show a higher WTP to reduce the outage frequency. Second, highly-educated respondents, those who state a great concern for the greenhouse gases emissions and those who carry out energy saving actions in their homes exhibit a larger WTP for renewable energies. This empirical evidence provides useful information for authorities responsible for energy policy design.

14/01311 Tensions in implementing the 'energy-conservation/carbon-reduction' policy in Taiwanese culture

Chiu, M.-S. *Energy Policy*, 2013, 55, 415–425.

The aim of this study is to investigate the Taiwanese public's perceptions of tensions between the implementation of an energy policy and the practice of traditional culture. The energy policy calls for public actions to conserve energy and reduce carbon emissions. The research participants are 94 people, selected by balancing sexes, ages, and residential areas, from a wide range of vocations. The research data were collected by semi-structured interview with the participants individually. Interview questions were designed to elicit the participants' constructs, beliefs, behaviours and tensions in relation to energy policy and traditional culture. Data analysis was performed based on a qualitative methodology by the procedure of open coding, theme finding, constant comparison, and theory generation. The analysis identifies four tensions: (1) tensions in knowledge bases between energy conservation and carbon reduction, (2) tensions in lifestyles between having and being, (3) tensions in social systems between authority and conformity and (4) tensions in creation boundaries between technology and nature. The themes underlying the four tensions are uncertainty, pleasure, power, and control, respectively. Solutions to the four tensions may include practical knowledge, pragmatic idealism, hierarchical collaboration, and sustainable innovation.

14/01312 The analysis on solid cylindrical heat source model of foundation pile ground heat exchangers with groundwater flow

Zhang, W. *et al. Energy*, 2013, 55, 417–425.

This paper presents a solid cylindrical simulation model of heat transfer around foundation pile ground heat exchangers with groundwater flow for ground-coupled heat pump (GCHP) applications. The analytical solutions of the temperature response in the heat transfer process including heat conduction and convection were obtained. The impact of groundwater flow on the heat transfer has been investigated. The heat transfer processes with and without groundwater flow were compared. It was found that groundwater flow has a considerable effect on the heat transfer process, especially when the groundwater flow velocity attains a certain order of magnitude. If the system is designed reasonably and groundwater temperature is below a certain range, groundwater flow is favourable to the heat transfer between the foundation pile ground heat exchangers and surrounding ground medium, and can improve the energy performance of the heating and cooling system of the GCHP for energy conservation of buildings.

14/01313 Utilization and performance evaluation of a surplus air heat pump system for greenhouse cooling and heating

Yang, S.-H. and Rhee, J. Y. *Applied Energy*, 2013, 105, 244–251.

Energy conserving is an important issue in greenhouse farming. Because greenhouse operations consume large amount of fossil fuel energy, energy conservation is necessary for securing famers' income and alleviating global warming. Surplus air thermal energy (SATE) in greenhouses exists even in the cold season, but it has not been utilized for greenhouse operations. In this research, a greenhouse system to capture and use SATE for cooling and heating in greenhouse farming was operated and its performance was evaluated. This system consists of a heat pump system including heat storage tanks, fan-coil-units in the greenhouse and an electric heater for supplemental heating. This system was located in Hwasung, Korea and operated in the cold season. The amount of SATE was measured to be between 258.3 and 6259.0 MJ/month for a glass house with a 100 m^2 floor area. The energy conservations were determined to be maximum of daily 76.3% and monthly 25.7%.

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14/01314 A multivariable robust-adaptive control strategy for a recycled wastewater treatment bioprocess

Petre, E. and Selişteanu, D. *Chemical Engineering Science*, 2013, 90, 40–50.

This paper presents the design and analysis of a multivariable robust-adaptive control strategy for a continuous aerobic wastewater treatment bioprocess. The design procedure is developed under the realistic assumption that the bacterial growth rates are uncertain and the influent flow rates are disturbed, but some lower and upper bounds of these uncertainties (possibly time varying) are known. The control structure is achieved by combining a linearizing control law with an interval observer able to estimate lower and upper bounds of unmeasurable states. The performance of the control algorithms are illustrated by simulations performed for a recycled wastewater treatment bioprocess for which kinetic dynamics are highly non-linear, time-varying and incompletely known.

14/01315 Analysis of environmental and economic benefits of integrated exhaust energy recovery (EER) for vehicles

Peng, Z. *et al. Applied Energy*, 2013, 105, 238–243.

Differing from those traditional vehicle exhaust heat recovery systems which just provided thermal energy directly for cabin warming, integrated exhaust energy recovery (EER) which is researched and developed mainly in recent years aims to convert exhaust thermal energy to mechanical or electric energy for increasing the total thermal efficiency and the total power of powertrain. In the study presented in this paper, an analytic model was built for examining the environmental and economic benefits of integrated EER systems. Then the improvement on the total powertrain efficiency and net reduction of CO_2 emissions were investigated, in terms of the average vehicle used in the UK. Results show that, for light duty vehicles fitted with thermal cycle EER system, the cost increase could be paid back in 10.1 years and CO_2 emission could be paid back in just 1.9 years, compared to hybrid electric vehicles' (HEVs) 11.9 years and 1.4 years for cost and CO_2 emission, respectively. When the annual fuel price increase is considered, the cost pay-back is reduced to 8.1 years for EER vehicles and 8.9 years for HEVs. Higher mileage vehicles will have more obvious advantage for fitting EER system. When doubled annual mileage is considered, EER system can reduce the cost and CO_2 emission pay-back times to 2.7 years and 0.6 years, compared to HEVs' 8.5 and 2.7 years, respectively.

14/01316 Analysis of hybrid waste-to-energy for medium-sized cities

Balcazar, J. G. C. *et al. Energy*, 2013, 55, 728–741.

Urban centres have a huge demand for electricity and the growing problem of the solid waste management generated by their population, a relevant social and administrative problem. The correct disposal of the municipal solid waste (MSW) generated in cities is one of the most complex engineering problems that involves logistics, safety, environmental and energetic aspects for its adequate management. Due to a national policy of solid wastes recently promulgated, Brazilian cities are evaluating the technical and economic feasibility of incinerating the non-recyclable waste. São José dos Campos, a São Paulo State industrialized city, is considering the composting of organic waste for biogas production and mass incineration of non-recyclable waste. This paper presents a waste-to-energy system based on the integration of gas turbines to a MSW incinerator for producing thermal and electric energy as an alternative solution for the solid waste disposal in São José dos Campos, SP. A technical and economic feasibility study for the hybrid combined cycle plant is presented and revealed to be attractive when carbon credit and waste tax are included in the project income.

14/01317 Biodiesel production using oil from fish canning industry wastes

Costa, J. F. *et al. Energy Conversion and Management*, 2013, 74, 17–23.

The present study evaluated biodiesel production using oil extracted from fish canning industry wastes, focusing on pre-treatment and reaction conditions. Experimental planning was conducted to evaluate the influence of acid catalyst concentration (1–3 wt% H_2SO_4) in the esterification pre-treatment and the amount of methanolic solution (60–90 vol.%) used at the beginning of the further two-step alkali transesterification reaction. The use of a raw-material mixture, including waste oil obtained from olive oil bagasse, was also studied. The results from experimental planning showed that catalyst concentration mostly influenced product yield and quality, the best conditions being 1 wt% catalyst and 60 vol.% of methanolic solution, to obtain a product yield of 73.9 wt% and a product purity of 75.5 wt%. Results from a one-step reaction under the selected conditions showed no advantage of performing a two-step alkali process. Although under the best conditions several of the biodiesel quality parameters were in agreement with standard specifications, a great variation was found in the biodiesel acid value, and oxidation stability and methyl ester content did not comply with biodiesel quality standards. Aiming to improve fuel quality, a mixture containing 80% waste olive oil and 20% of waste fish oil was evaluated. Using such mixture, biodiesel purity increased around 15%, being close to the standard requirements (96.5 wt%), and the oxidation stability was in agreement with the biodiesel quality standard values ($\geq$6 h), which are promising results clearly showing the potential of using such wastes, of very low value, for biodiesel production.

14/01318 Design and optimisation of organic Rankine cycles for waste heat recovery in marine applications using the principles of natural selection

Larsen, U. *et al. Energy*, 2013, 55, 803–812.

Power cycles using alternative working fluids are currently receiving significant attention. Selection of working fluid among many candidates is a key topic and guidelines have been presented. A general problem is that the selection is based on numerous criteria, such as thermodynamic performance, boundary conditions, hazard levels and environmental concerns. A generally applicable methodology, based on the principles of natural selection, is presented and used to determine the optimum working fluid, boiler pressure and Rankine cycle process layout for scenarios related to marine engine heat recovery. Included in the solution domain are 109 fluids in subcritical and supercritical processes, and the process is adapted to the properties of the individual fluid. The efficiency losses caused by imposing process constraints are investigated to help propose a suitable process layout. Hydrocarbon dry type fluids in recuperated processes produced the highest efficiencies, while wet and isentropic fluids were superior in non-recuperated processes. The results suggested that at design point, the requirements of process simplicity, low operating pressure and low hazard resulted in cumulative reductions in cycle efficiency. Furthermore, the results indicated that non-flammable fluids were able to produce near optimum efficiency in recuperated high pressure processes.

14/01319 Development of a continuous process for the hydroformylation of long-chain olefins in aqueous multiphase systems

Rost, A. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 67, 130–135.

The challenging task of homogeneous catalysis is the efficient combination of reaction and catalyst recycling. In the hydroformylation of long-chain olefins generally cobalt-based catalysts are used, but in this investigation rhodium-based catalysts were used, because of their higher activity in comparison to cobalt catalysts. In hydroformylation reactions, the recycling of the expensive rhodium catalyst as well as the selectivity to linear aldehydes are very challenging. Multiphase systems offer the possibility to increase the interfacial area during reaction on the one hand and to separate the metal–ligand complexes easily from the organic product phase after reaction, to recycle the expensive catalyst for further reactions, on the other hand. Solubilizers such as surfactants or polar solvents can be used to formulate such a tuneable solvent system. Upon cooling of the reaction mixture, phase separation is achieved. Based on that combination of reaction and phase separation for catalyst recycling, a novel process concept was developed for the hydroformylation of long-chain olefins. In order to show the applicability of that concept in a continuous process a fully automated miniplant was designed.

14/01320 Effects of exhaust gas recycle in a downsized gasoline engine

Galloni, E. *et al. Applied Energy*, 2013, 105, 99–107.

Lately, the exhaust gas recycle usage, widely diffused in diesel engines, has been adopted in spark ignition (SI) engines as well. It is a cheap technique which allows a sound control of NO formation meanwhile it can improve engine thermodynamics. In this paper, the influence of exhaust gas recycling (EGR) on the operation of a turbocharged SI engine has been evaluated by using both experimental and numerical techniques. In particular, since knock occurrence is a crucial point in the optimization of a turbocharged SI engine, the improvement in knock resistance, at high load operation, has been assessed. First, a method for knock detection and quantification has been illustrated. Then, the influence of EGR on engine performance, octane requirement and exhaust gas temperature was measured at two different rotational speed values and wide-open throttle operation. Since EGR has produced a drop in engine performance (between 10% and 13%) and an increase in knock resistance, a new set of main control variables has been determined in order to restore the original torque level while achieving a significant decrease in specific fuel consumption (between 6% and 11%). The results of the experimental tests highlighted that, keeping the engine control parameters unvaried, EGR produces a performance reduction and an increase in specific fuel consumption with respect to the pure air–fuel feeding. At the same time, the charge dilution induces a strong reduction of both the burnt gas temperature and the knock intensity. Using EGR, the same torque level provided by the undiluted charge, can be obtained by plugging the gap in volumetric efficiency by means of higher turbocharging ratios. The tests here carried out demonstrated that EGR operation allows higher boost pressure values and leaner air–fuel mixtures at a given knock intensity level. In particular, when EGR is used, a proper optimization of the main engine control variables (i.e. boost pressure, air-to-fuel ratio and spark advance) allows achieving the same performance level of the engine running with pure air–fuel charge, meanwhile the exhaust temperature and knock intensity remain unvaried and the specific fuel consumption significantly decreases.

14/01321 Energy recovery of date palm residues in a domestic pellet boiler

Elmay, Y. *et al. Fuel Processing Technology*, 2013, 112, 12–18.

This work presents a preliminary study on the energy recovery of two date palm residues (date stone and date rachis) provided from Tunisia. Rachis residues were transformed into pellets while date stones were used as received. Physicochemical characteristics such as ultimate and proximate analyses and calorific values were determined. Date palm residues were combusted in a domestic pellet boiler according to European EN 303–5 standard. High calorific values of both residues as well as combustion efficiencies close to 80% obtained during combustion tests indicate that these residues are a promising alternative to produce renewable energy in Tunisia. Further adjustments (airflow and fuel feed rates) are necessary to improve boiler efficiencies. High air excess were observed and consequently cooled down the fume temperature. CO and dust emission factors were in the same order of magnitude than expected for EN 303–5 certification. Bottom and fly ashes were characterized by DRX and Fluorescence X. With high contents of chlorine and ash in the rachis pellets, combustion of this sample leads to high emission factors of dust. Further investigations are required for rachis pellets to reach biofuel standards. Elemental chlorine remains in solid residues as bottom and fly ashes under Halite and Sylvite species.

14/01322 Experimental study on organic Rankine cycle for waste heat recovery from low-temperature flue gas

Zhou, N. *et al. Energy*, 2013, 55, 216–225.

An experimental system for heat recovery from low-temperature flue gas based on organic Rankine cycle (ORC) was constructed. In the system, R123 was selected as working fluid, a scroll expander was used to produce work, and fin tubes heat exchanger was designed as evaporator. Low-temperature flue gas produced by an liquefied petroleum gas stove was used as the heat source to simulate industrial flue gas, and its temperature can be controlled in the range of 90–220 °C. Relationships between output performance of the system and the evaporating pressure, temperature of the heat source as well as the superheat degree of the working fluid were investigated. The results show that the cycle efficiency, the output power of the expander and its exergetic efficiency increase while the heat recovery efficiency decreases with the increment of the evaporating pressure at a certain temperature of the heat source. The influence of the superheat degree of the working fluid on the system output parameters is slight. Under the present experimental conditions, the maximum output power of the expander is 645 W, and the cycle efficiency and the heat recovery efficiency are 8.5% and 22%, respectively.

14/01323 Hydrothermal catalytic gasification of fermentation residues from a biogas plant

Zöhrer, H. and Vogel, F. *Biomass and Bioenergy*, 2013, 53, 138–148.

Biogas plants, increasing in number, produce a stream of fermentation residue with high organic content, providing an energy source which is by now mostly unused. The authors tested this biomass as a potential feedstock for catalytic gasification in supercritical water ($T \geq 374\,°C$, $p \geq 22\,MPa$) for methane production using a batch reactor system. The coke formation tendency during the heat-up phase was evaluated as well as the cleavage of biomass-bound sulfur with respect to its removal from the process as a salt. The authors found that sulfur is not sufficiently released from the biomass during heating up to a temperature of 410 °C. Addition of alkali salts improved the liquefaction of fermentation residues with a low content of minerals, probably by buffering the pH. The authors found a deactivation of the carbon-supported ruthenium catalyst at low catalyst-to-biomass loadings, which are attributed to sulfur poisoning and fouling in accordance with the composition of the fermentation residue. A temperature of 400 °C was found to maximize the methane yield. A residence time dependent biomass to catalyst ratio of $0.45\,g\,g^{-1}\,h^{-1}$ was found to result in nearly full conversion with the Ru/C catalyst. A Ru/ZrO_2 catalyst, tested under similar conditions, was less active.

14/01324 Methods for improving heat exchanger area distribution and storage temperature selection in heat recovery loops

Walmsley, M. R. W. *et al. Energy*, 2013, 55, 15–22.

Inter-plant heat integration across a large site can be achieved using a heat recovery loop (HRL). In this paper the interrelationship between HRL storage temperatures, heat recovery and total HRL exchanger area is investigated. A methodology for designing a HRL based on a $\Delta T_{\min}$ approach is compared to three programming optimization approaches where heat exchangers are constrained to have the same number of heat transfer units, log-mean temperature difference or to find the absolute minimum total area for a given heat recovery level. Analysis is performed using time-averaged and transient mass flow rate data and temperature data. The actual temperature driving force of the HRL heat exchangers is compared to the apparent driving force as indicated by the composite curves. Results for the same heat recovery level show that the $\Delta T_{\min}$ approach is effective at minimizing total area to within 5% of the minimum area approach. Allocation of individual heat exchanger areas can vary widely depending on the optimization method, the characteristics of the transient stream data and the differences in the approach and exit stream temperatures. Results suggest that using the $\Delta T_{\min}$ method for selecting storage temperatures in combination with sizing exchangers based on the time average heat capacity flow rates (for while the process is running) gives a near optimal solution without requiring lots of data input or computing resources.

14/01325 Optimal design of thermoelectric devices with dimensional analysis

Lee, H. *Applied Energy*, 2013, 106, 79–88.

The optimum design of thermoelectric devices (thermoelectric generator and cooler) in connection with heat sinks was developed using dimensional analysis. New dimensionless groups were properly defined to represent important parameters of the thermoelectric devices. Particularly, use of the convection conductance of a fluid in the denominators of the dimensionless parameters was critically important, which leads to a new optimum design. This allows us to determine either the optimal number of thermocouples or the optimal thermal conductance (the geometric ratio of footprint of leg to leg length). It is stated from the present dimensional analysis that, if two fluid temperatures on the heat sinks are given, an optimum design always exists and can be found with the feasible mechanical constraints. The optimum design includes the optimum parameters such as efficiency, power, current, geometry or number of thermocouples, and thermal resistances of heat sinks.

14/01326 Optimum design of dual pressure heat recovery steam generator using non-dimensional parameters based on thermodynamic and thermoeconomic approaches

Naemi, S. *et al. Applied Thermal Engineering*, 2013, 52, (2), 371–384.

The thermodynamic and thermoeconomic analyses are investigated to achieve the optimum operating parameters of a dual pressure heat recovery steam generator (HRSG), coupled with a heavy-duty gas turbine. In this regard, the thermodynamic objective function including the exergy waste and the exergy destruction, is defined in such a way to find the optimum pinch point, and consequently to minimize the objective function by using non-dimensional operating parameters. The results indicated that, the optimum pinch point from thermodynamic viewpoint is 2.5 and 2.1 °C for HRSGs with live steam at 75 and 90 bar, respectively. Since thermodynamic analysis is not able to consider economic factors, another objective function including annualized installation cost and annual cost of irreversibilities is proposed. To find the irreversibility cost, electricity price and also fuel price are considered independently. The optimum pinch point from thermoeconomic viewpoint on basis of electricity price is 20.6 °C (75 bar) and 19.2 °C (90 bar), whereas according to the fuel price it is 25.4 and 23.7 °C. Finally, an extensive sensitivity analysis is performed to compare optimum pinch point for different electricity and fuel prices.

14/01327 Overview of the production of biodiesel from waste cooking oil

Yaakob, Z. *et al. Renewable and Sustainable Energy Reviews*, 2013, 18, 184–193.

In recent years, biodiesel has attracted significant attention from researchers, governments, and industries as a renewable, biodegradable, and non-toxic fuel. However, several feedstocks have been proven impractical or infeasible because of their extremely high cost due to their usage primarily as food resources. Waste cooking oil (WCO) is considered the most promising biodiesel feedstock despite its drawbacks, such as its high free fatty acid (FFA) and water contents. This review paper provides a comprehensive overview of the pre-treatment and the usage of WCO for the production of biodiesel using several methods, different types of reactors, and various types and amounts of alcohol and catalysts. The most common process in the production of biodiesel is transesterification, and using a methanol–ethanol mixture will combine the advantages of both alcohols in biodiesel production. In addition, this paper highlights the purification and analysis of the produced biodiesel, operating parameters that highly affect the biodiesel yield, and several economic studies. This review suggests that WCO is a promising feedstock in biodiesel production.

14/01328 Performance comparison and working fluid analysis of subcritical and transcritical dual-loop organic Rankine cycle (DORC) used in engine waste heat recovery

Shu, G. *et al. Energy Conversion and Management*, 2013, 74, 35–43.

In this paper, a new dual-loop organic Rankine cycle (DORC) consisting of a high-temperature (HT) cycle and a low-temperature (LT) cycle is proposed to recover the waste heat of the exhaust and the engine coolant and the residual heat of the HT cycle. Two different systems are adopted. According to the cycle mode adopted in the LT cycle, the system can be defined as subcritical–subcritical (sub–sub) DORC or subcritical–transcritical (sub–trans) DORC. R125, R143a and R218 are chosen as the candidate working fluids in the LT cycle of the sub–trans DORC, while R124, R134a, R245fa, R600, R600a and R1234yf are the candidates of the sub–sub DORC. Net output power and exergy efficiency are selected as the objective functions. Results show that R143a-based sub–trans DORC system performs the best and the net output power and the exergy efficiency are 39.91 kW and 48.42%, respectively. Small condensation temperature of the HT cycle is advantageous for the performance optimization. Irreversibilities of evaporator E_{HT}, condenser C_{LT} and the two turbines (T_{HT} and T_{LT}) are the top four, which are the optimization objectives. For R143a-based sub–trans DORC, system performs best with 100% operating load.

14/01329 Production possibility frontier analysis of biodiesel from waste cooking oil

Kagawa, S. *et al. Energy Policy*, 2013, 55, 362–368.

This paper presents an assessment of the productive efficiency of an advanced biodiesel plant in Japan using data envelopment analysis (DEA). The empirical analysis uses monthly input data (waste cooking oil, methanol, potassium hydroxide, power consumption, and the truck diesel fuel used for the procurement of waste cooking oil) and output data (biodiesel) of a biodiesel fuel plant for August 2008 to July 2010. The results of this study show that the production activity with the lowest cost on the biodiesel production possibility frontier occurred in March 2010 (production activity used 1.41 kL of waste cooking oil, 0.18 kL of MeOH, 16.33 kg of KOH and 5.45 kW h of power), and the unit production cost in that month was ¥18,517/kL. Comparing this efficient production cost to the mean unit production cost on the production possibility frontier at ¥19,712/kL, revealed that the cost of producing 1 kL of biodiesel could be reduced by as much as ¥1195. The authors also find that the efficiency improvement will contribute to decreasing the cost ratio (cost per sale) of the biodiesel production by approximately 1% during the study period (24 months) between August 2008 and July 2010.

14/01330 Recycling and reuse of spent microalgal biomass for sustainable biofuels

Rashid, N. *et al. Biochemical Engineering Journal*, 2013, 75, 101–107.

The use of microalgal biomass (MAB) for biofuel production has been recognized since long. Despite distinct advantages of algal biofuels, however, their sustainability and economic viability is still doubtful. Overall process cost and low energy recovery need to be significantly improved. The use of MAB, after extracting primary fuels in the form of hydrogen, methane, biodiesel and bioethanol, can be one promising route. This algal biomass, collectively termed as spent microalgal biomass (SMAB), contains even up to 70% of its initial energy level and also retains nutrients including proteins, carbohydrates, and lipids. Potential application routes include diet for animals and fish, the removal of heavy metals and dyes from wastewater, and the production of bioenergy (e.g. biofuels and electricity). Unlike whole algae biomass whose applications are relatively well documented, SMAB has been studied only to limited degree. Therefore, this work gives a brief overview of various ways of SMAB applications. An insight into current status, barriers and future prospects on SMAB research is provided. The feasibility of each application is evaluated on the basis of its energy recovery, economic viability, and future perspectives are provided.

14/01331 The prospects of electricity generation from municipal solid waste (MSW) in Ghana: a better waste management option

Ofori-Boateng, C. *et al. Fuel Processing Technology*, 2013, 110, 94–102.

In 2010, the total generated municipal solid waste (MSW) in Ghana was 4.5 million tons. About 90% of the total MSW generated is not effectively managed but dumped in unauthorized places creating serious burden on human health. With a population growth rate of about 3.4% per year, Ghana is predicted to face big challenges in waste management. One effective way of managing solid waste is to recover the potent energy from them through waste-to-energy (WTE) plants such as engineered landfilling and controlled incineration. Cost assessment of power generation based on MSW in Ghana showed that the average cost of electricity for landfill gas power plants with already existing closed engineered landfill emerged as the cheapest (US$0.039/kWh) compared to landfilling without engineered sites and controlled incineration. Moreover, the average domestic employment per megawatt energy generated is higher at approximately 185 for existing engineered landfills compared to the other technologies. Engineered landfill sites are under construction in Ghana whose average power extraction would be between 1 and 2 MW. Thus a potentially sustainable way of managing MSW in Ghana is through the construction of WTE plants to generate electricity.

14/01332 Utilization of waste heat from a HCCI (homogeneous charge compression ignition) engine in a tri-generation system

Sarabchi, N. *et al. Energy*, 2013, 55, 965–976.

The waste heat from exhaust gases and cooling water of homogeneous charge compression ignition engines (HCCI) are utilized to drive an ammonia-water cogeneration cycle (AWCC) and some heating processes, respectively. The AWCC is a combination of the Rankine cycle and an absorption refrigeration cycle. Considering the chemical kinetic calculations, a single zone combustion model is developed to simulate the natural gas fuelled HCCI engine. Also, the performance of AWCC is simulated using the engineering equation solver software. Through combining these two codes, a detailed thermodynamic analysis is performed for the proposed tri-generation system and the effects of some main parameters on the performances of both the AWCC and the tri-generation system are investigated in detail. The cycle performance is then optimized for the fuel energy saving ratio (FESR). The enhancement in the FESR could be up to 28.56%. Under optimized condition, the second law efficiency of proposed system is 5.19% higher than that of the HCCI engine while the reduction in CO_2 emission is 4.067% as compared with the conventional separate thermodynamic systems. Moreover, the results indicate that the engine, in the tri-generation system and the absorber, in the bottoming cycle has the most contribution in exergy destruction.

14/01333 Waste fish oil biodiesel as a source of renewable fuel in Iran

Yahyaee, R. *et al. Renewable and Sustainable Energy Reviews*, 2013, 17, 312–319.

This study presents a brief introduction to the resource, status and prospect of waste fish oil as a sustainable energy source for biodiesel production in Iran. The fish oil was separated from fish wastes with the help of a designed oil extraction machine. Experiments showed that 53% of fish wastes was in liquid phase (mixture of water, oil and suspended solids) and the extracted oil was about 11% of the total weight of the fish wastes (from 7 kg of wastes, about 3.71 kg liquid was extracted and 0.81 (768 g) oil was isolated). Biodiesel fuel was then produced from the extracted fish oil after the chemical reaction (transesterification, reaction between methanol, potassium hydroxide and oil from fish waste). In this investigation, for each litre of produced fish oil, 0.91 biodiesel was produced. Important fatty acids like palmeitoleic, palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid were identified for the extracted oil. The highest fatty acid ratio belonged oleic acid. These fatty acids affect the magnitude of the cetane number of biodiesel fuel.

14/01334 Thermodynamic investigation of low-temperature industrial waste-heat recovery in combined heat and power generation systems

Etemoglu, A. B. *International Communications in Heat and Mass Transfer*, 2013, 42, 82–88.

Performance analysis of an industrial waste heat-based combined heat and power systems (WHCHP) completely uses energy and exergy efficiency parameters. The effect of waste water mass flow rate, pressure and temperature, organic fluid types on both energy and exergy efficiencies and economical profit of the system is investigated by a computer simulation. The first step of the analysis is the selection of the suitable working fluid. After that, in order to get the performance indicators, different scenarios are run by computer simulation for WHCHP. The most suitable working fluid is found out as isopentane. The work output and economical profit increase while exergy destruction decreases with increasing turbine inlet pressure. On the other hand, with the increase in the energy of the process heater, the work output decreases but exergy destruction and utilization factor increase. Finally, these results clearly show that performance evaluation of WHCHP based on energy analysis is not adequate and hence more meaningful evaluation should include exergy analysis.